The Proceedings of the Geophysical Society of Tulsa

Volume 5 1957-58

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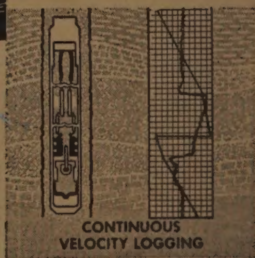

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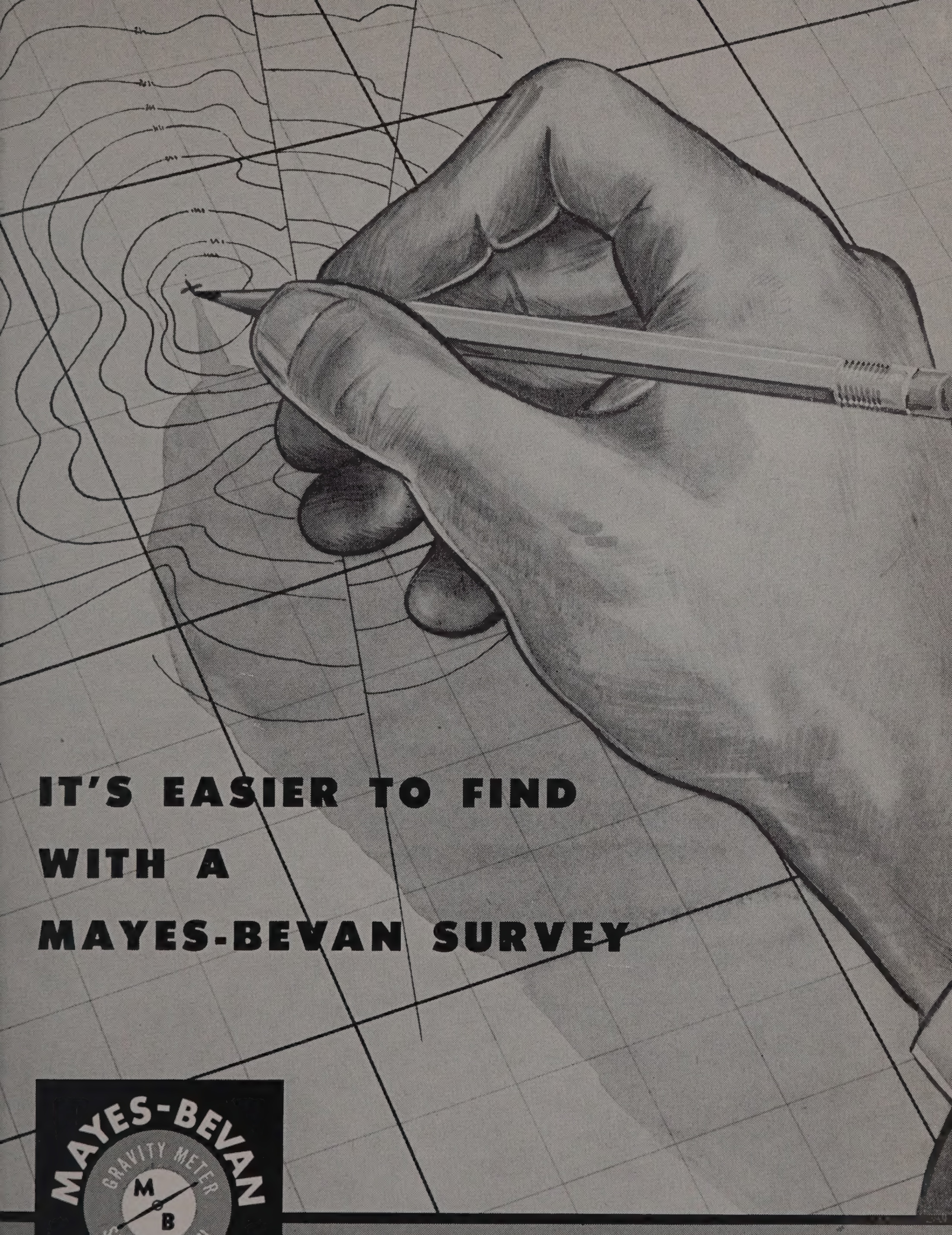
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PROCEEDINGS OF THE GEOPHYSICAL SOCIETY OF TULSA

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Volume 5, 1957-58

R. L. FROSSARD, *Editor*

JAMES F. JOHNSON, *Assistant to the Editor*

W. O. NOVELLY, *Business Manager*

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EDITOR'S FOREWORD

The Editor of the Society for the 1957-58 term, Dr. M. B. Widess, was transferred to Fort Worth, Texas, late in 1957. The vacancy created by his resignation was filled by appointment.

We are indebted to Dr. Widess for originating the project entitled *Abstracts of Papers and Lectures Given Before Other Local Sections of SEG, 1957-58.* This feature is presented as a step toward alleviating the chronic dearth of communication between Local Sections of SEG. Thanks are gratefully extended to the officers of the Local Sections who assisted in accumulating the abstracts.

Special thanks are due the contributors of the original papers presented in this issue. Their kindness and cooperation made the labors of publishing a rewarding experience.

The financial success of this issue is due to the efforts of the Business Manager, W. O. Novelly, who performed an onerous task with skill and dispatch.

FIRST HONORARY MEMBERSHIP AWARDED BY THE GEOPHYSICAL SOCIETY OF TULSA

Dr. William Schriever

At the regular monthly meeting of The Geophysical Society of Tulsa which was held in Ponca City on April 10, 1958, the Executive Committee unanimously elected Dr. William Schriever, Professor of Physics at the University of Oklahoma, as the first Honorary Member of the Society. The presentation of the award was made on April 17th, at the opening session of the Eleventh Annual Midwestern Exploration Meeting, which was held in Tulsa.

The award was made in recognition of Dr. Schriever's valuable contributions to publications, research, and many years of teaching geophysics and allied fields.

In presenting the award, Frank Searcy, President of the Society, made the following remarks:

"In 1929 at the University of Oklahoma, the first course in geophysics to be taught in this state was initiated. Teaching this course in the Physics Department at that time and continuing for 29 years, was Dr. William Schriever. Including a current class of fourteen, 408 students have been enrolled in this course. Two hundred and eighty of these are listed as members of the Society of Exploration Geophysicists, and many of them are now leaders in the geophysical industry.

"Dr. Schriever has been engaged in teaching and research at the University of Oklahoma for 39 years. He received his A.B. from Morningside College in 1916, and his M.S. and Ph.D. degrees from the University of Iowa in 1917 and 1921 respectively. He served as Chairman of the Department of Physics at O.U. from 1942 to 1952, and was Director of the School of Enginneering Physics from 1942 to 1948. He has published a total of 39 research papers in various technical journals, a number of these have been in GEOPHYSICS, and two were published in Volume IV of The Proceedings of the Geophysical Society of Tulsa. At the university he has conducted several fundamental research problems in geophysics.

"Dr. Schriever is a fellow in the American Physical Society, and also of the AAAS. He is a member of the SEG, the AGU, American Association of Physics Teachers, and Sigma Xi.

"In recognition of the high esteem in which Dr. Schriever is held by former students and others who know him and are familiar with his work, The Geophysical Society of Tulsa considers it an honor and a privilege to make him the first Honorary Member of our Society as is his just due as 'Dean of Geophysics' in the state of Oklahoma. We deeply regret that Dr. Schriever's health will not permit him to be present this morning. On his behalf, one of his former students, Mr. V. L. Jones, will accept this honorary membership and will present Dr. Schriever's paper, Para and Diamagnetic Susceptibilities in Non-fluctuating Weak Fields."

The acceptance of the award by V. L. "Vic" Jones follows:

"President Frank Searcy, ladies and gentlemen; I deeply regret that Dr. Schriever is unable to be present with us to accept this award. I feel highly honored, and am most happy that he has designated me to act in his behalf at this time.

"I have known Dr. Schriever for nearly 37 years, and consider him one of my closest friends. About a week or so ago, when it was determined that he could not be present at this meeting, he sent me the following acceptance message to be read on this occasion: 'To the Executive Committee and members of The Geophysical Society of Tulsa, ladies and gentlemen; I have long admired the vigor and the enthusiasm of The Geophysical Society of Tulsa, the first local section of the Society of Exploration Geophysicists. Some of your members I have counted among my best friends for many years. Many of these friends I had the good fortune to know as students in my classes at the University of Oklahoma at Norman. A number of these friendships began more than 35 years ago.

" 'So it is indeed a very great pleasure for me to accept Honorary Membership in The Geophysical Society of Tulsa. I deem it a great honor which my family and I shall cherish through the years to come. I thank you sincerely.' signed, William Schriever.

"President Searcy, on behalf of Dr. Schriever, I accept this Honorary Membership in The Geophysical Society of Tulsa for him. Thank you."

Professor Schriever's paper, *Para and Diamagnetic Susceptibilities in Non-fluctuating Weak Fields*, was presented on the second day of the Eleventh Annual Midwestern Exploration Meeting by Vic Jones. The published text of this paper will be found in the October, 1958 issue of GEOPHYSICS.

In 1933, Dr. Schriever presented his meteoric hypothesis on the origin of the Carolina Bays, and has published the following papers on the subject: *The Carolina Bays—Are They Meteorite Scars?* (with F. A. Melton), Journal of Geology 41, 52-66, 1953 (reprinted in full in The Scientific American);

On the Origin of the Carolina Bays, Transactions of the American Geophysical Union 32, 87-95, 1951; *Discussion of "On the Origin of the Carolina Bays"* (by J. S. Rinehart with closure by Wm. Schriever), Transactions of the American Geophysical Union 33, 126-127, 1952; *Were the Carolina Bays Oriented by Gyroscopic Action?* Transactions of the American Geophysical Union 36, 465-469, 1955; *Discussion of "Were the Carolina Bays Oriented by Gyroscopic Action"* with closure by Wm. Schriever, Transactions of the American Geophysical Union 37, 112-117, 1956.

Other important papers published by Professor Schriever on geophysical and allied subjects are as follows: *Law of Flow for a Gas-Free Oil Through a Spherical-Grain Sand,* Transactions American Institute of Mining & Metallurgical Engineers (Petroleum Development and Technology), pp 329-336, 1930; *Sound Ranging in a Medium Having a Constant Phase Velocity*, GEOPHYSICS 17, 915-923, 1952; *Reflection Seismograph Prospecting—How it Started*, GEOPHYSICS 17, 936-942, 1952; *Streaming Potential in Spherical-Grain Sands* (with Carl Bleil), Journal of the Electrochemical Society 104, 170-176, 1957; *The Locus of Points Having Equal Arrival-Times for a Reflected Wave*, Proceedings of The Geophysical Society of Tulsa 4, 19-20, 1956-57; *Vector Composition of Reflection Time-Gradients,* Proceedings of The Geophysical Society of Tulsa 4, 25-27, 1956-57.

Dr. Schriever was a fellow of the American Petroleum Institute during the period 1927-29. He served in the Signal Corps of the U. S. Army during World War I. His biography has appeared in *Who's Who in America* since 1946.

As this issue of the *Proceedings* goes to press, it has just been learned that the Executive Committee of SEG has unanimously elected Dr. Schriever to Honorary Membership in the national parent organization, to which we add our hearty congratulations.

The formal presentation of this high honor will be made on October 13, at the opening session of the annual meeting which will be held in San Antonio.

HOW THIN IS A THIN BED?

By

M. B. Widess*

ABSTRACT

Based on reflective properties, a thin bed may be conveniently defined as one whose thickness is less than about $\lambda_b/8$, where λ_b is the (predominant) wave length computed using the velocity of the bed. The amplitude of a reflection from a thin bed is to the first order of approximation equal to $4\pi Ab/\lambda_b$, where b is the thickness of the bed and A is the amplitude of the reflection if the bed were to be very thick. The equation shows that a bed as thin as 10 ft. has, for typical frequency and velocity, considerably more reflective power than is usually attributed to it.

For an unknown reason the geophysical industry appears to have grown up with some misconceptions on the reflective properties of so-called thin beds. What is the reflective behavior of thin beds? How thin must the bed be before the reflection has negligible amplitude? Our purpose is to consider such questions in elementary terms.

GRAPHICAL ILLUSTRATION OF A TIME DERIVATIVE OF A WAVELET

Let us first examine the algebraic difference of two identical wavelets which are displaced slightly in time. Referring to Fig. 1A, wavelets R_1 and $-R_2$ are identical except for the time difference ΔT between them. Vertical lines between R_1 and $-R_2$ mark the difference in amplitude at successive simultaneous times, and this difference R_d is plotted in Fig. 1B. The following properties of R_d are evident. (1) Wavelet R_d has *zero* amplitude in each half cycle at a time close to midway between the times when R_1 and $-R_2$ are at their *maximum* amplitude. That is, there is a 90° phase shift between R_d and the mean of R_1 and $-R_2$, the phase being advanced in time. (2) Correspondingly, whereas R_1 exhibits an "M" form of character (when considering strongest peaks and trough), R_d has an "S" form of character (when considering strongest peak and trough). (3) The first maximum (a trough) of R_d arrives earlier than the first maximum (a trough) of R_1, and the last maximum (a peak) of R_d arrives later than the last maximum (a trough) of R_1. In total, R_d has a half cycle more than does R_1, and this incidentally is associated with a greater relative content of high frequency in R_d than in R_1.

The wavelet R_d is clearly the reflection from a thin bed, Fig. 1C, when the acoustic impedance (product of velocity and density) in the medium above the bed is the same as that in the medium below the bed, R_1 being the reflection from the top interface and R_2 from the bottom interface (transmission loss and multiple reflections being neglected). The negative sign attached to R_2 in Fig. 1A of course accounts for the phase inversion at the bottom interface in this example. The time displacement ΔT is equal to $2b/V_b$ for vertical incidence, where b is the thickness of the bed and V_b is the velocity of the bed.

Since R_d is the difference between identical wavelets that are displaced in time, R_d approximates the time derivative of R_1 when the time displacement

*Pan American Petroleum Corporation, Fort Worth, Texas

is small. It is significant however that the *form* of the wavelet R_d still closely approximates the derivative of R_1 even when b is as great as 1/8 of the wave

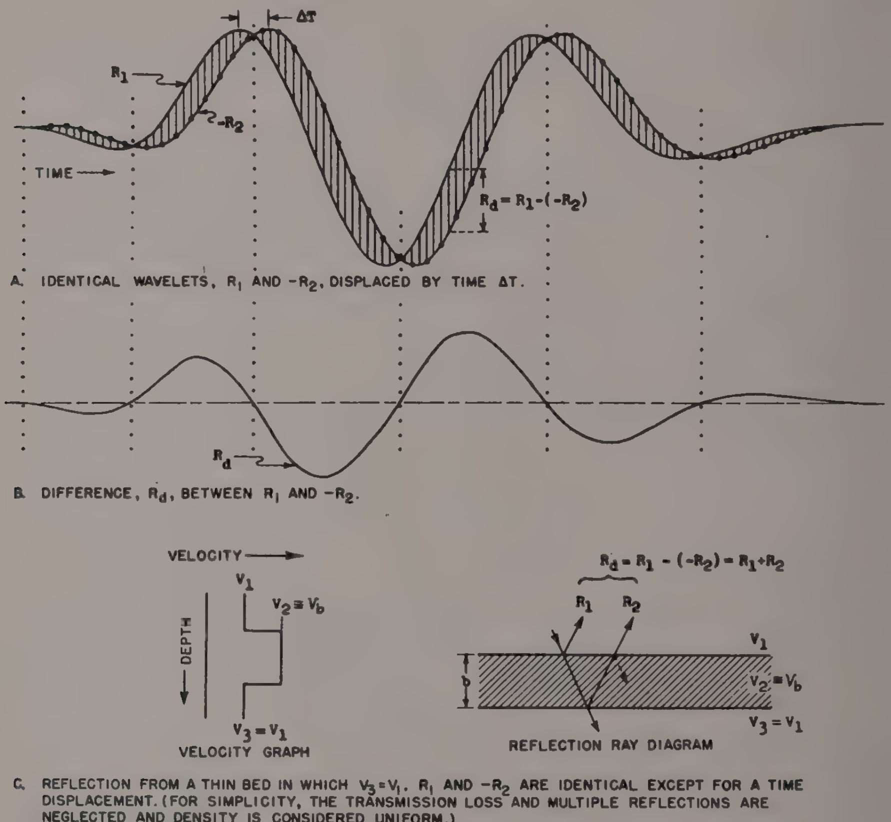


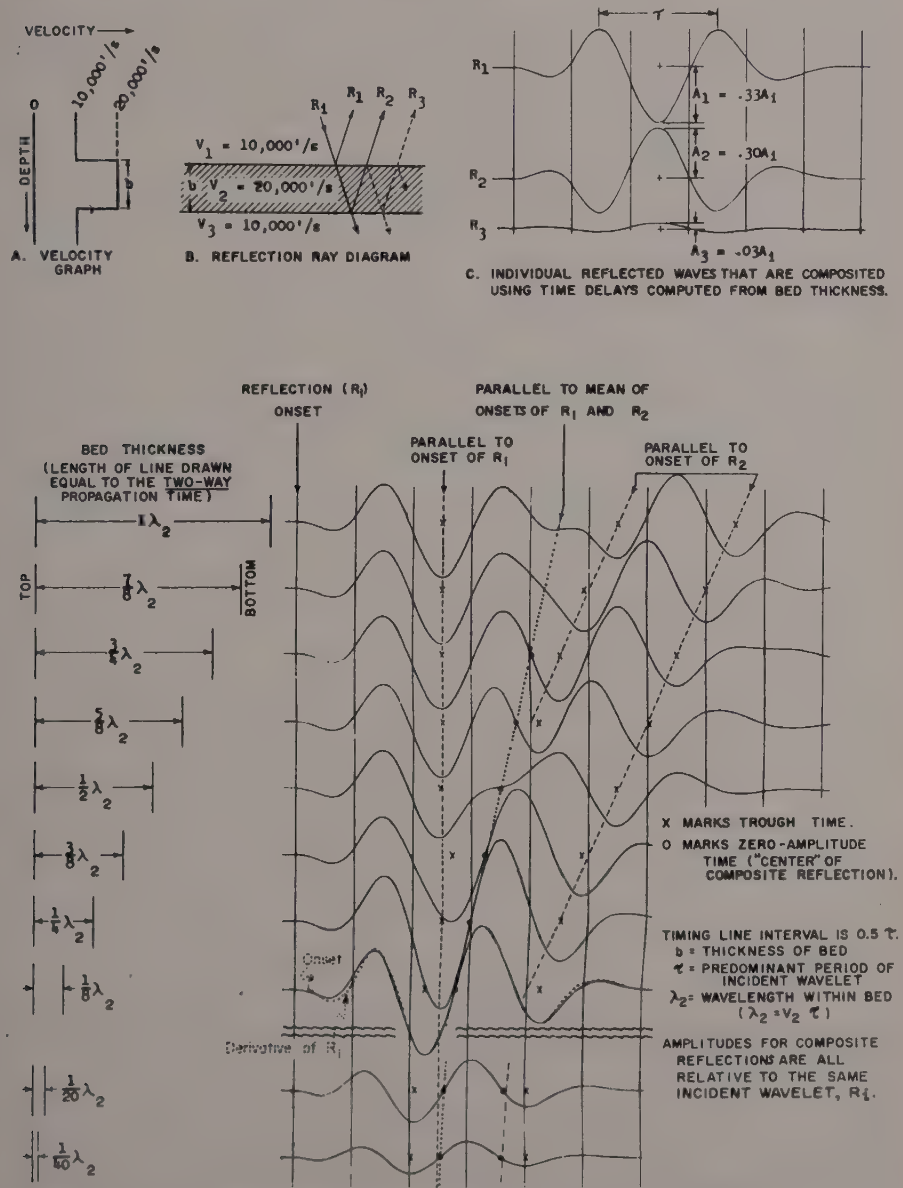
FIG. 1 Illustrating the phase shift and change in character resulting from the difference of identical wavelets displaced slightly in time.

length λ_b computed using the velocity in the bed ($\lambda_b = \tau V_b$, where τ is the predominant period of the wavelet). This is illustrated in the next figure to be discussed.

EFFECT OF BED THICKNESS ON REFLECTION CHARACTER AND TIMING

The traces in Fig. 2D show reflections from a progressively thinner bed. As before, the velocity above the bed is the same as that below the bed, Fig. 2A. The velocity of the bed itself is twice that of the superjacent and subjacent media. The wavelets R_1 and R_2 reflected from the upper and lower interfaces respectively, as well as the first-order multiple R_3, are shown in Fig. 2C in terms of the amplitude A_1 of the incident wavelet R_1. The relations are for vertical incidence, and density changes are neglected. The first-order multiple reflection is so weak that for our present purposes it could also have been neglected, as are the higher order multiple reflections. The traces in

Fig. 2D were derived arithmetically by compositing R_1, R_2, and R_3 in a time relation corresponding to the respective bed thicknesses. The traces exhibit interplay between reflections from the top and bottom interfaces of the bed, producing destructive interference for $b=\lambda_b/2$ and constructive interference especially for $b=\lambda_b/4$. Our attention however is to be directed toward the still thinner beds, where constructive interference is at first still active but



D. FORM AND RELATIVE TIMING OF COMPOSITE REFLECTION AS A FUNCTION OF BED THICKNESS.

FIG. 2 Illustrating effect of bed thickness on the reflection.

with successively thinner beds destructive interference proceeds to extinguish the reflection.

When the bed is very thin, the character of the reflection is that of the time derivative of the incident wavelet and the timing is dictated by the time to the center of the bed. That substantially the same character and timing exist for bed thickness as great as about $\lambda_b/8$ is demonstrated on the trace for that bed thickness. The time derivative of the incident wavelet is shown there by the dotted-line wavelet, and we see that this almost duplicates the reflection on that trace. (In drawing the time derivative wavelet, its amplitude was increased by a constant factor to match the amplitude of the reflection on the trace, and the onset of the time derivative wavelet was located at the mean of the onset times of R_1 and R_2.) Thus, insofar as bed thickness alone is concerned, the character of the reflections is indistinguishable for beds whose thickness is less than about $\lambda_b/8$. For that reason it is appropriate to define a thin bed as one whose thickness is less than about $\lambda_b/8$. Two-way time through a thin bed would then be less than about $\tau/4$. A bed that is thin for one frequency is of course not necessarily thin for a higher frequency.

EFFECT OF BED THICKNESS ON REFLECTION AMPLITUDE

To the first order of approximation the central portion of wavelet R_1 in Fig. 1 may be treated as a sine wave whose maximum amplitude A is the mean between the amplitudes of the predominant peak and trough of R_1. This simplification permits an easy derivation of the approximate amplitude of reflection R_d from a thin bed. Referring zero time t_o to the mean of the deep-trough times of R_1 and $-R_2$, the equations for the central portion of R_1 and $-R_2$ respectively are then

$$R_1 \cong -A \cos (t+b/V_b)\, 2\pi/\tau \qquad (1)$$

and

$$-R_2 \cong -A \cos (t-b/V_b)\, 2\pi/\tau, \qquad (2)$$

where t is the time relative to t_o and τ is the predominant period of the wavelet. By expanding the two equations and taking the difference, we obtain

$$R_d = R_1 + R_2$$

$$\cong [2A \sin 2\pi b/\tau V_b] \sin 2\pi t/\tau. \qquad (3)$$

The term in brackets is approximately the maximum amplitude A_d of wavelet R_d. To the first order of approximation in the case of a thin bed,

$$\sin 2\pi b/\tau V_b \cong 2\pi b/\tau V_b.$$

So that $A_d \cong 4\pi Ab/\tau V_b$.

Since $\lambda_b = \tau V_b$, we have* $A_d \cong 4\pi Ab/\lambda_b \qquad (4)$

Therefore for thin beds the amplitude of the reflection is approximately pro-

* The exact equation for reflection from a single imbedded layer, considering simple harmonic waves and accounting for transmission loss (but not absorption loss), is given in Rayleigh "The Theory of Sound", Vol. II p. 88, Dover Publ. 1945 Ed. The equation, adapted to our notation, is

$$A_d = A\,(1+r)^2\,[(2r \cot 2\pi b/\lambda_b)^2 + (1+r^2)^2]^{-1/2},$$

where r is the ratio of acoustic impedances. The quantity A_d obtained from this equation differs from A_d in Eq. 4 by no more than only 12% when the bed is thin, $b/\lambda_b < 1/8$, and when $1/2 < r < 2$, the range of acoustic contrast usually encountered in practice.

portional to the thickness of the bed and inversely proportional to the wave length.

We note that reflections from beds that are generally considered very thin are not necessarily restricted to small amplitudes. For example, if $b/\lambda_b = 1/20$ we have $A_d \cong 0.6A$. That is, in a typical case of a reflection whose predominant frequency is 50 cps and a bed whose velocity is 10,000 ft./sec., the wave length λ_b is 200 feet, so that a bed whose thickness is only 10 feet would still have about 0.6 of the amplitude that would result if the bed were very thick. If the bed were to be only 5 feet thick, the factor would still be fairly large, namely 0.3 instead of 0.6. These magnitudes may be seen in the bottom two traces respectively of Fig. 2D, comparing them with the top trace.

The above conditions apply only to thin beds for which the two media bounding the bed have the same acoustic impedance. The relations do not apply when the two bounding media have appreciably different acoustic impedance, since in that case not only is a thin bed involved but also an acoustic change in the absence of the thin bed. It is then generally sufficiently accurate to consider that the reflection from the bed is a composite of the following two reflections: (1) the reference reflection, namely the reflection which would result in the absence of the thin bed and (2) the time-derivative type of reflection associated with the thin bed itself, for which the acoustic impedance above and below the bed is the same and is equal to the acoustic impedence of the medium which the bed replaces. The effect of the thin bed may then be reckoned in terms of the relative strength and phase relation between the reference reflection and the time-derivative reflection. The relation may be shown readily by vectorial representation.

RESOLVING POWER

A definition of the term "thin bed" involves the concept of resolving power. Resolving power is the ability to distinguish between the properties of two (or more) elements. The elements that we have been considering here are the reflecting interfaces of a bed. Resolving power is illustrated in Fig. 2 as follows. When bed thickness b is large enough that the individual reflected wavelets from each of the two interfaces are completely separated in time, the trace on the record of course potentially yields maximum possible information for each of the interfaces. As the bed thickness diminishes, more and more of the energy becomes a composite for the two reflections. That is, there is successively less data for each of the reflections separately but more data in the form of combination of the two reflections. This trend continues until the thickness is equal to about $\lambda_b/8$. For this and still thinner beds, substantially the only information left is for the combination of the two reflections and therefore substantially none for the individual reflections.* At that point therefore, resolving power may be said to be lost and the point may be loosely called the theoretical threshold of resolution. Practically, a num-

* The fact that information only on a combination of reflections is available means that substantially the same reflection can be obtained for a very wide assortment of thin beds, which in themselves may consist of different laminae. It may therefore be of interest to state that to the first order of approximation the only conditions which these beds must fulfill to qualify in this assortment are the following: (1) the overall bed must be thin; (2) the total area between the time vs. velocity curve and the reference velocity line must be the same for the overall bed, treating the respective areas of the bed algebraically relative to the reference velocity line; (3) the geometric center of this area must be at the same record time, again considering the respective areas algebraically relative to the reference velocity line.

ber of other factors are involved that will determine the threshold of resolution. For example, with the presence of noise the broadening of the wavelet from $b = \lambda_b/8$ to $b = \lambda_b/4$ in Fig. 2 may be obscured, thus forcing the threshold of resolution to the thicker bed. The threshold of resolution therefore depends not only on the predominant frequency of the incident wavelet but also on the signal-to-noise ratio. Still other factors include the form and duration of the incident wavelet, the degree to which this wavelet is known prior to the analysis, and the analytical tools used.

When the whole of a thin bed rather than the individual interfaces is to be considered, a different threshold of resolution is brought into play. For example, if either the velocity system or the bed thickness remains constant, the change of bed thickness or velocity respectively can be determined under favorable circumstances for a bed whose thickness is considerably less than $\lambda_b/8$. Measurements are then made on the change in reflection time and/or the change in reflection amplitude.

SEISMIC EXPLORATION IN THE APPALACHIAN REGION

By

LELAND SNOW*

INTRODUCTION

Surface geology has provided a wealth of structural information in the Appalachian region since the birth of the anticlinical theory of oil accumulation. The value of seismic data is realized from the more detailed delineation of faulting and axes positions at depth on known anticlines, and in routine exploration to discover gas and oil traps where surface indications are obscure.

A large number of seismic surveys, individually of rather limited coverage, have been conducted in the region in Pennsylvania, New York, Delaware, Maryland, Virginia, West Virginia, and Kentucky. Geophysical exploration in recent years has mainly been confined to the general area in and west of the Appalachian folds. This paper pertains principally to the province east of the axis of the Appalachian geosyncline, and summarizes seismic objectives, methods, and problems.

OBJECTIVES

Most of the operators in the region are companies or individuals who are primarily interested in gas production. There is a ready market and the price is good. Long experience has proved that the Onondaga limestone and the Oriskany sandstone (Lower Devonian) are the principal gas producing formations, and are almost always productive where structural conditions are favorable. Local operators believe that faulting often improves permeability of the gas pays. The Onondaga-Oriskany zone is the usual drilling objective, but there is increased interest in the Clinton (Silurian) for oil production and a few Clinton tests are scheduled.

OPERATIONS

Shooting permits are not difficult to obtain and usually no payment is required. The drilling conditions range from good to very poor. In western New York and Pennsylvania, for example, one drill may get as many as ten holes per day, while in the sharply folded regions where there are steeply dipping outcrops two heavy air-water combination drills may do well to get four or five holes per day. In the latter areas several rock bits may be used in drilling 70 feet. Holes deeper than 100 feet are seldom required. The region is generally insensitive and charges of 50 pounds or more are sometimes necessary, particularly where loading a second charge might be impossible.

Tape recording is as applicable here as in most areas. It has advantages, certainly, but the chances of finding favorable well locations that might be

* Petty Geophysical Engineering Company

missed with conventional equipment are considered slight. Eight or more geophones per trace are desirable when spaced with regard to the topography. The geophone spread is a standard split, or end-on-end if distances between shotpoints need to be increased. Cross-spreads are used occasionally for mapping resultant dips. This method yields valuable information in the sharply folded areas but is hardly feasible as a matter of routine because of the terrain and expense. Dual recording for taking mixed and unmixed seismograms simultaneously has been helpful.

PROGRAMMING

Very little pure reconnaissance shooting is done. Leases considered attractive have been held for years by gas companies and most of the recent seismic work is on known anticlines, and on anomalies postulated from subsurface data or geologic concept.

Roads and trails are first utilized for the seismic lines even though probably not located for optimum control. In rough terrain many of the roads follow the drainage pattern, are narrow, and near considerable culture such as dwellings, water wells, and power lines. Active mines and old mined out areas are located and avoided. Where the field conditions are very severe the lines are not tied together. All this makes it difficult to obtain adequate control and presents one of the major problems. As the mapping progresses, indications of where critical control is needed may develop and then bulldozed roads are made.

COSTS

Over-all costs to the operator vary widely from one part of the region to another. A fairly low figure per shothole would be $175.00 but this could easily run over $300.00 when several rocks bits are used and roads "dozed". Costs can be reduced on longer range programs as moving and "hot shot" expense, and higher cost due to adverse weather conditions will be more evenly distributed.

The effects of inflation are felt in the monthly charge for seismic work, however the over-all cost to the operator is lower now than at the time of the early work in the region. This is attributable to improved instrumentation and geophone arrays that reduce the number of NG seismograms, and the introduction of air drilling. An intangible but very important factor is the greater understanding of the problems by both the geophysicists and the operators' geologists.

STRUCTURE

Figure 1 illustrates the major regional structural features. Many prominent anticlines are not shown. Figure 2 is a generalized, vertically exaggerated northwest-southeast cross-section across Barbour, Randolph, and Pendleton Counties, West Virginia. The anticlines are sharply folded and highly faulted. The major faults are thrusts, and when near and paralleling anticlinical axes there is often a shift of the axes with depth. Doming appears to be associated with the faulting in a number of instances.

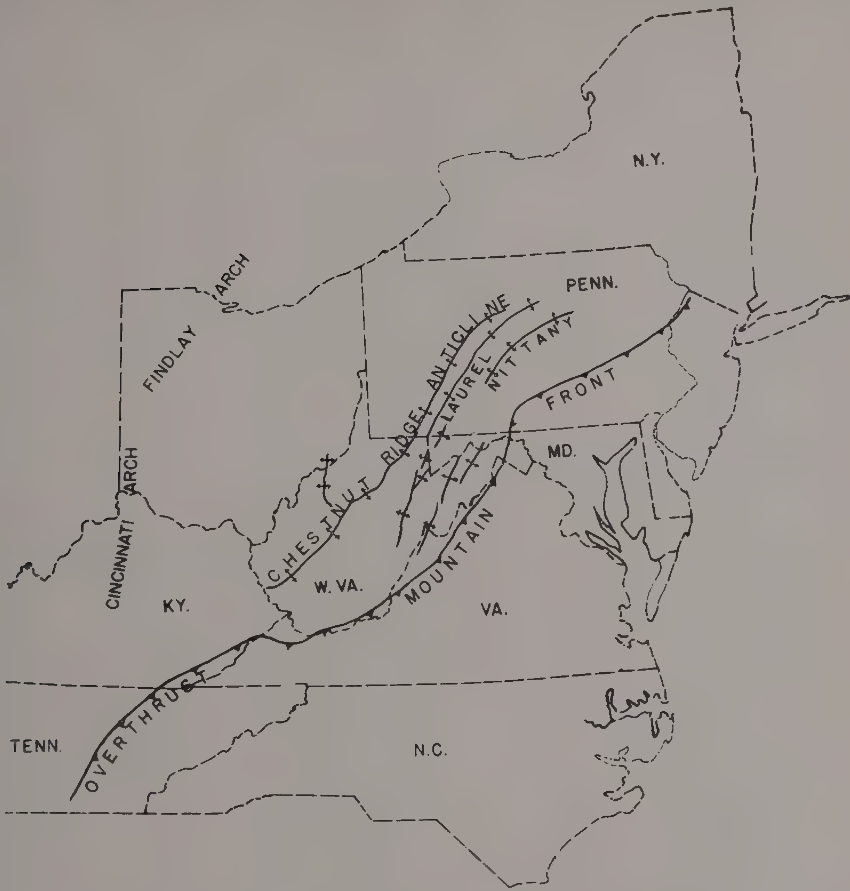


FIG. 1. Major structural features of the Appalachian region.

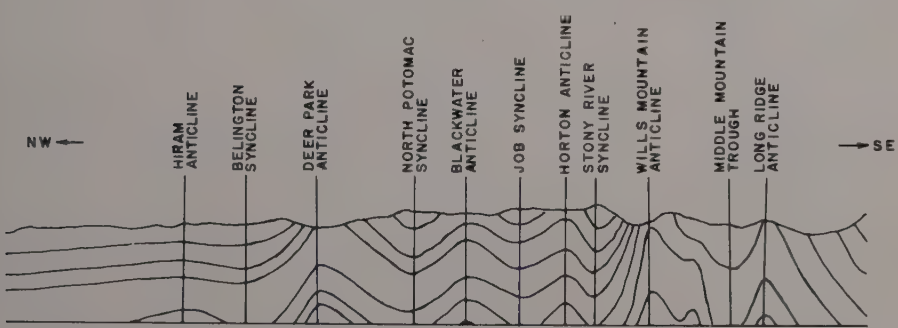


FIG. 2. Generalized cross-section through Barbour, Randolph and Pendleton Counties, West Virginia. (Adapted from Geologic Map of West Virginia)

VELOCITIES

Very few velocity determinations have been made in the region. Figure 3 is the graph and seismogram of a velocity survey made in West Virginia in 1941. It shows relatively high velocities from the near-surface down to total

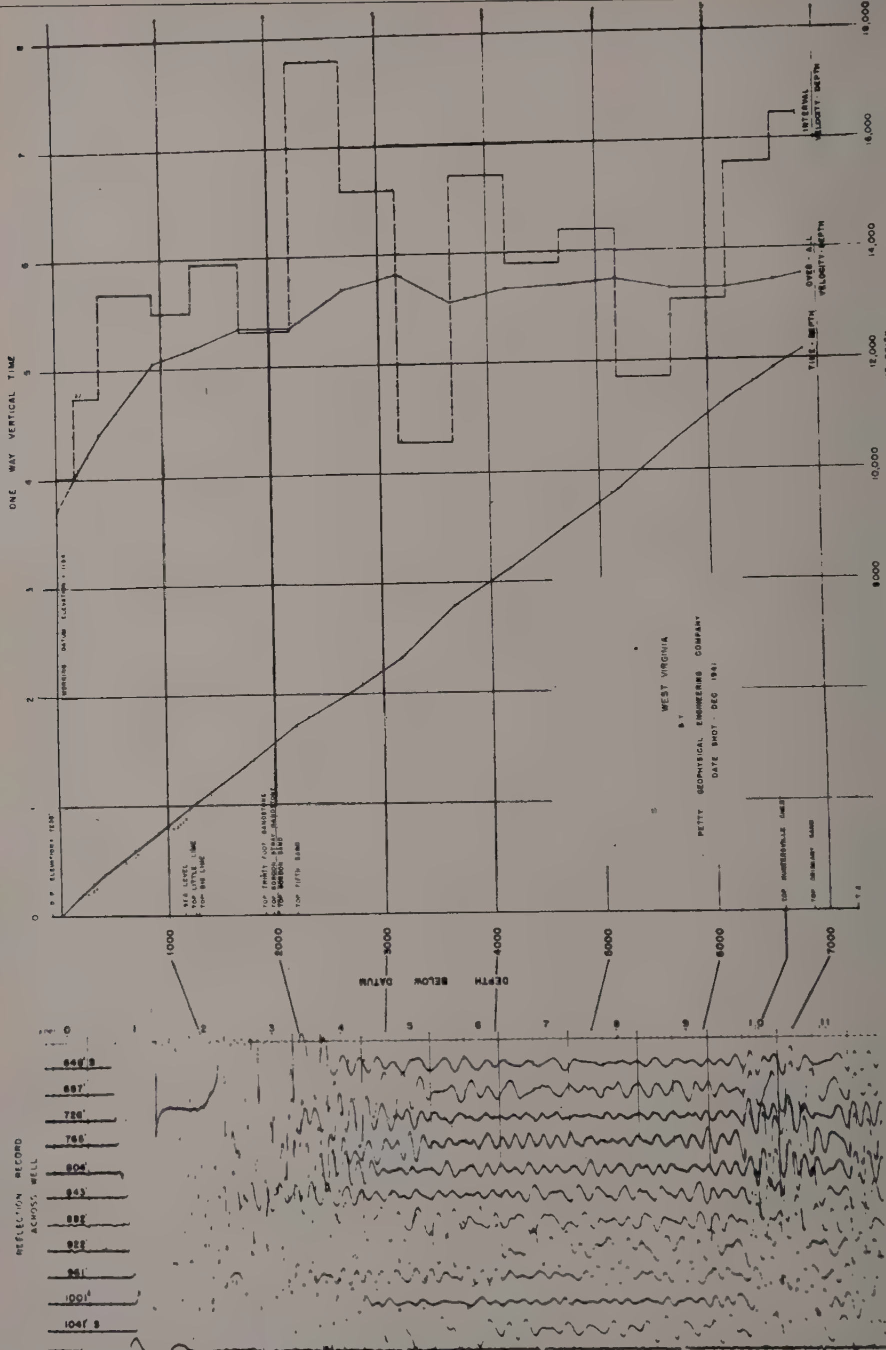


FIG. 3. Graph and reflection seismogram of a velocity survey made in West Virginia in 1941. The deepest point surveyed is in the Oriskany sandstone.

depth in the Oriskany. These data, with variations, have been used extensively and have proved reasonably accurate in predicting Onondaga depths. Near-

surface velocities are usually rather high but should be studied for variation along river bottoms and on low-relief structures.

INTERPRETATION

Referring to Figure 4, record "A" is a good specimen seismogram taken in

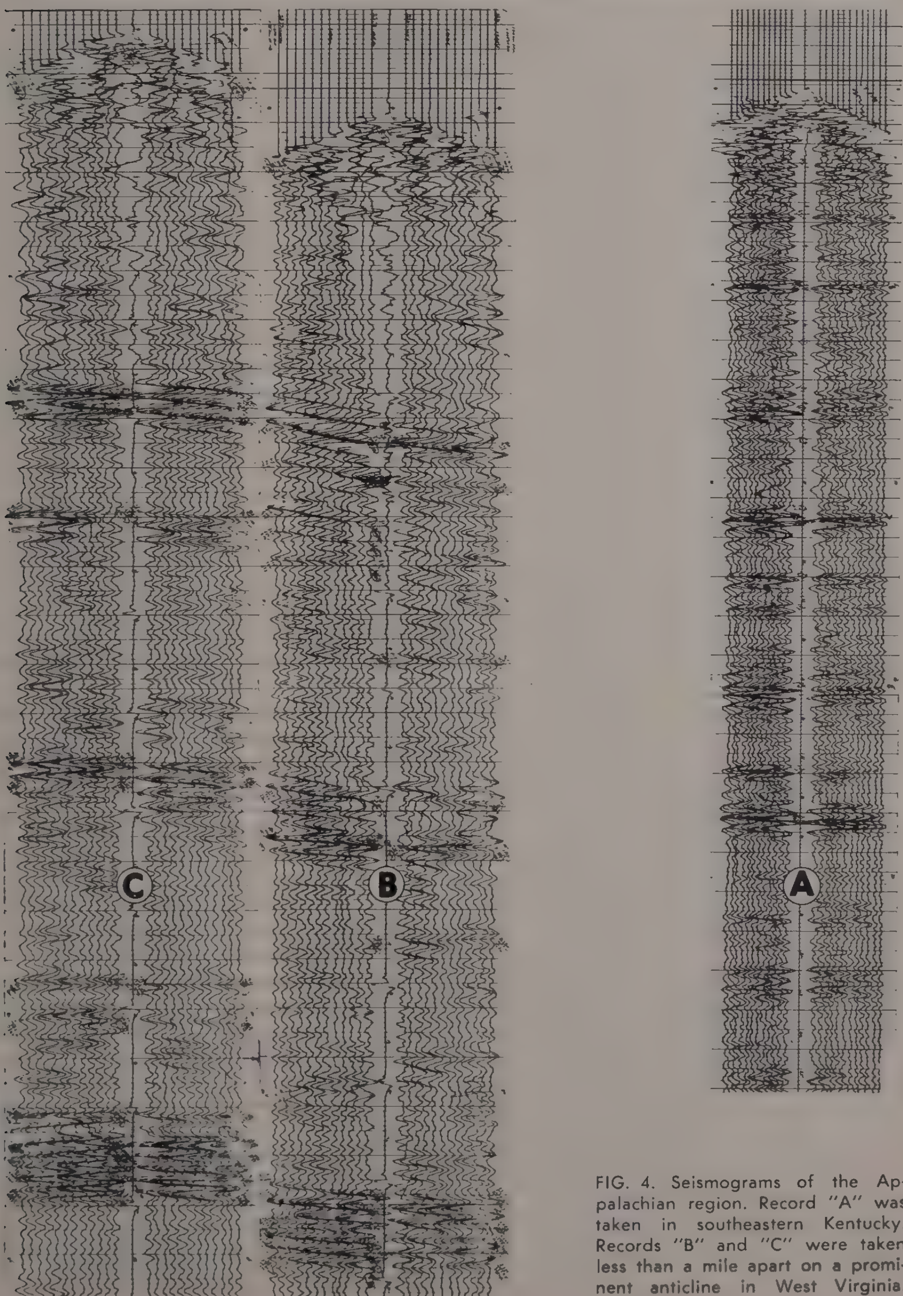


FIG. 4. Seismograms of the Appalachian region. Record "A" was taken in southeastern Kentucky. Records "B" and "C" were taken less than a mile apart on a prominent anticline in West Virginia.

southeastern Kentucky. In several areas the seismograms are of spot correlation quality with persistent reflections including Onondaga, Lower Ordovician, and what is tentatively identified as "basal sand". Records "B" and "C" were taken less than a mile apart on a prominent anticline in West Virginia, and were selected to illustrate the difference in interval that is accounted for by dip and slight faulting on the shallower reflector. Absence of sub-surface information in this area precludes identification of the reflections but the early one is assumed to be Onondaga. The crest of the structure is highly folded and faulted and shows a lengthened interval between the shallow and deep events.

In general, for the New York, Pennsylvania, and West Virginia province east of the geosynclinal axis, the outstanding reflections are from the Tully limestone (Devonian), the Onondaga-Oriskany zone, the Silurian in some areas, and an unidentified deep reflector. The Onondaga-Oriskany interval is too thin to be differentiated on the seismograms. The Tully is absent near the axis of the geosyncline and the interval down to the Onondaga thickens from about 300 feet in western Pennsylvania to 2000 feet in the northeastern part of the state.

The frequent lack of adequate control magnifies the seismologist's prob-

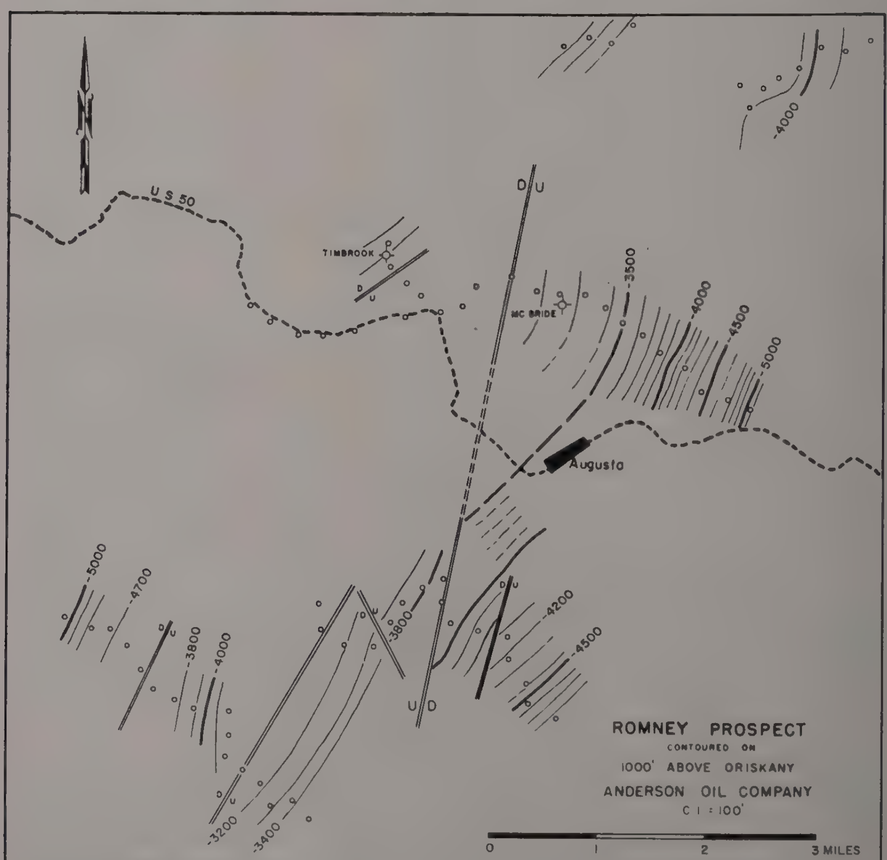


FIG. 5. Preliminary seismic map indicating that the McBride dry hole is favorably located.

lems in mapping a complex prospect. Figures 5 and 6 show how easily erroneous conclusions can be drawn. Figure 5, a map of preliminary work, indicates the McBride well was favorably located. The illogical scissors fault interpretation was made because it seemed that the small V-shaped fault block with the -3000 contour was structurally too high to be in the same fault block with the

FIG. 6. Same area as Figure 5 showing results of additional seismic control and consequent discovery well.

McBride well. Figure 6 illustrates the results of more detailed coverage. Later drilling developed this prospect into a very lucrative gas field.

A prospect on which several dry holes had been drilled on or near the surface axis of an anticline proved to be rather unusual. The first lines shot across the structure seemed to substantiate the interpretation made from surface geology. The seismograms on the flanks of the surface structure were of fair quality but deteriorated to very poor or NG near the axis as might be expected. Further shooting revealed that a subsurface graben underlay the surface high and subsequently production has been found on the flanks. Segments of this prospect have been shot every year since 1953 and since the shooting,

14 producers and one dry hole have been drilled. Figure 7 shows an idealized cross section of this prospect.

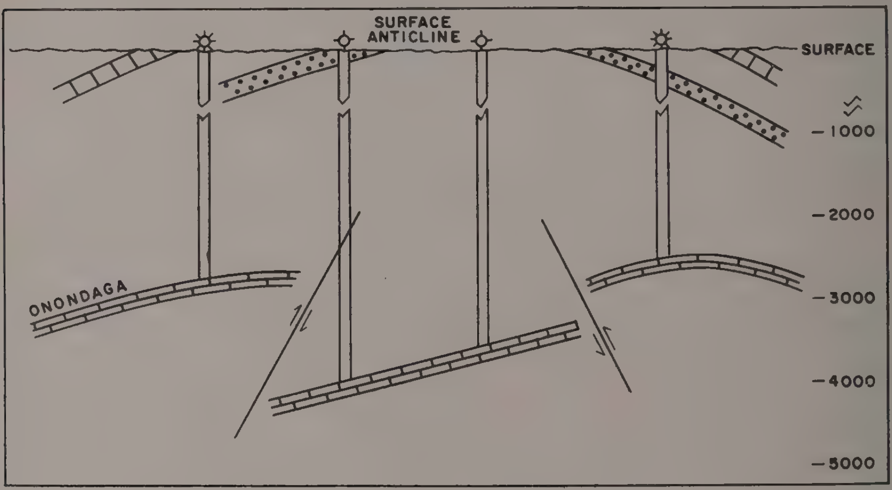


FIG. 7. Generalized cross-section of an unusual Appalachian case history showing dry holes drilled on surface anticline. Seismic survey revealed a central graben and flank traps which proved productive.

CONCLUSIONS

Procedures in conducting seismic surveys in the Appalachian region are not unique, and similar problems are encountered in other areas. Seismic information has proved valuable in locating gas fields that may have been missed when structural interpretation was made entirely on surface geology. A few poorly located tests may condemn an important field.

In the writer's opinion, there are important deeper oil traps in the Appalachian region that have not been tested because of the present demand for gas.

The writer wishes to thank Mr. Homer E. Roberts of the Petty Geophysical Engineering Company for some of the illustrations.

TOPOGRAPHY AND ITS APPARENT EFFECT ON AVERAGE VELOCITY

(In an Area of Low Structural Relief in Oklahoma)

By

H. M. Thralls*

INTRODUCTION

Developments and improvements in seismic instrumentation and field techniques during the past ten years have provided the oil industry with improved prospecting tools. The spectacular nature of some of the new gadgetry has encouraged the seismologist to lapse even further into the already lax attitude of indifference toward some of his fundamental problems. Much of the research and development has been directed toward improvement of record quality and the placement of information onto display sections so as to allow management and other non-geophysical personnel to be impressed with basic data. All this is well and good. However, there still remain a number of problems facing the seismologist which cannot, and will not, be solved by improved record quality.

The only geophysical interpretation of merit is that which resolves observed physical data into accurate geological predictions. Such an interpretation requires an awareness of all basic factors which contribute (in the case of seismology) to the time increments from which a conclusion must be drawn. The purpose of this paper is to flood light, so to speak, one of the most commonly ignored factors, the effect of changes in topographic overburden on velocity.

ORIGINAL SEISMIC INTERPRETATION

The geophysical prospect discussed as an illustration was shot during the year 1949 by a reputable contract organization for an independent oil company who has released this information for public presentation. The survey was completed with dispatch, the records were of fair quality, and the continuity of reflections was unquestionable. The interpretation was based on the accepted usage of up-hole times for weathered layer correction and the reduction of all data to an elevation plane selected to conform with the average position of the explosive charge. Surface elevations were observed only at the shothole location and the adjacent geophone stations, a practice which is relatively common and standard with certain operators.

Figure 1 contains two sample records chosen at random to illustrate record quality. Although they may not meet the requirements of excellent records, they are of reliable quality.

* Geo Prospectors, Inc.

FIG. 1. Sample records of subject area.

Figure 2 represents the potential structure as depicted by a reflection designated "Viola" by the original interpreter. If one accepts these data and the identification as made, the computed average velocities at the control points are 11,020 ft/sec, 11,160 ft/sec, and 11,085 ft/sec. This variation in velocity emphasizes that some sort of "correction factor" is needed to make the seismic survey check the control points. Many schemes can be used to accomplish this end, the most common and easiest to devise (and possibly the most mis-

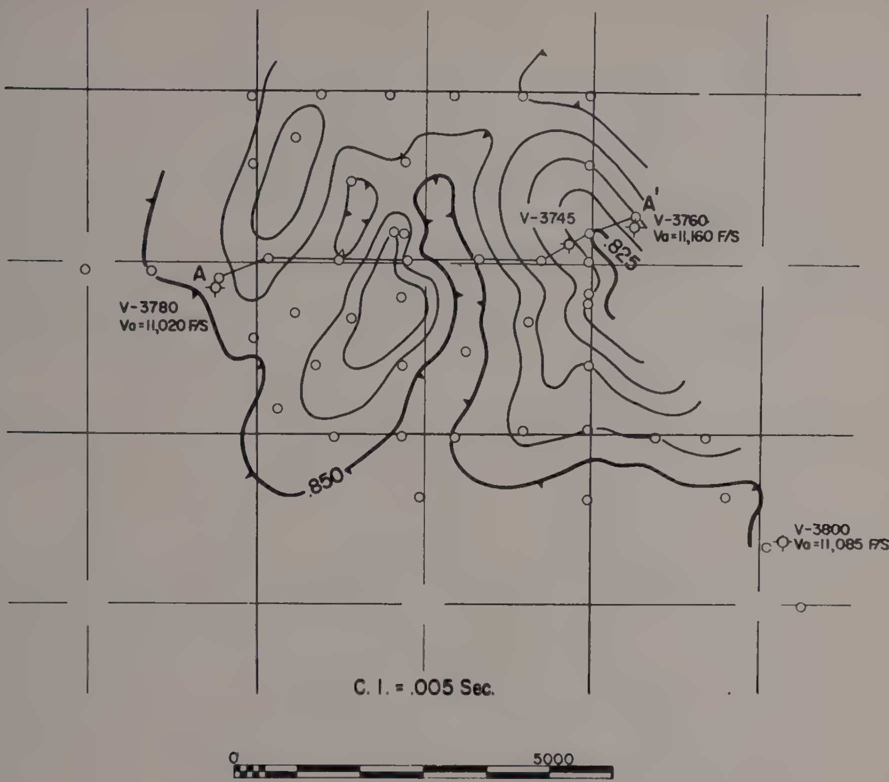


FIG. 2. Original time map of "Viola" reflection with computed average velocities at three dry holes.

leading) being a velocity gradient varying with geographical position.

The original depth map was not available to the writer. For the purpose of illustration, an average of the computed velocities listed above (11,090 ft/sec.) was used to convert time values into the depth values shown by Figure 3. Comparison of well data with seismic data or predicted depths indicates approximate mis-ties of +30 feet, –30 feet and 0 feet at the three points of control. These figures indicate that the expected accuracy, barring the use of additional corrections, will be no better than ±30 feet. The problem can be sized up in a general way by stating that the procedures used probably are satisfactory for outlining structures with 100 feet of relief but entirely unsatisfactory for features of 50 feet of relief. This yardstick, applied to Figure 3 gives the feature at the right side of the map a positive rating but places the low relief feature in the central part of the map in a questionable category. The latter feature because of its limited relief may not be there at all.

Structural features having less than 50 feet of relief are of economic importance in the vicinity of the prospect. Consequently the methods used are not sufficiently accurate to make a positive evaluation of all acreage covered.

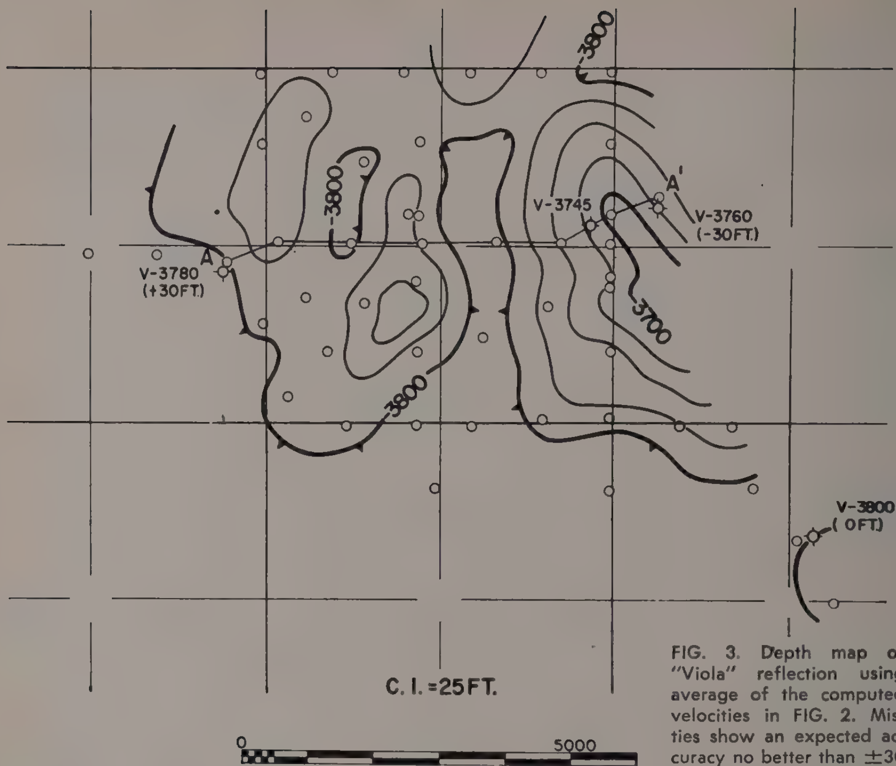


FIG. 3. Depth map of "Viola" reflection using average of the computed velocities in FIG. 2. Misties show an expected accuracy no better than ±30 feet.

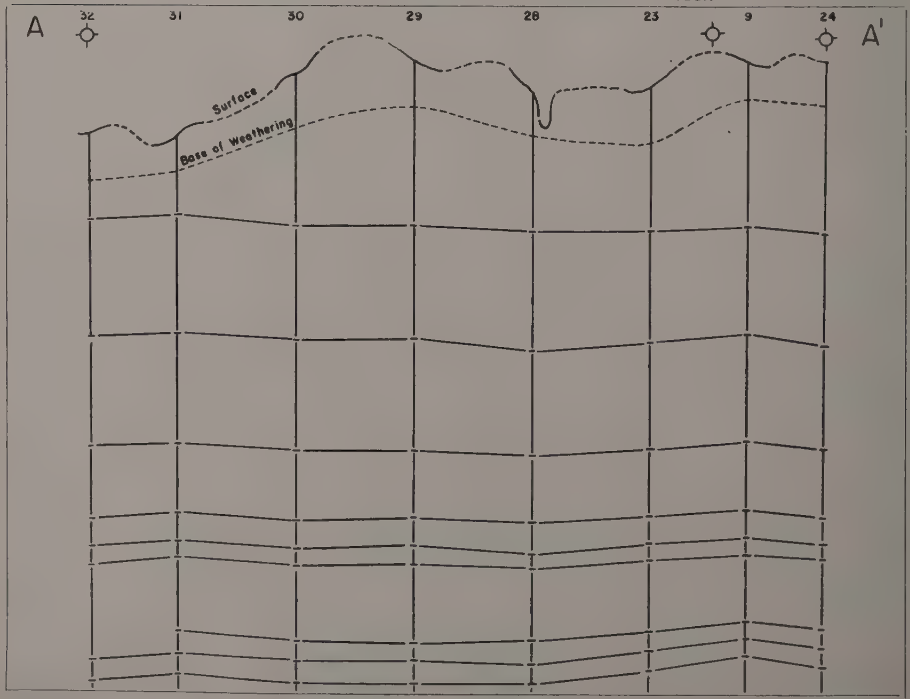


FIG. 4. Cross-section A—A′ connecting two control points and showing topographic variations.

The control points on any survey are equivalent to the answers we had as boys in the back of our arithmetic book. If, in working our problems we failed get the printed answer, we had to work them again. The same is true of this problem; our answers are not satisfactory so we must do it over.

On each of the maps shown, the position of cross-section A-A' (Figure 4) is indicated. It connects two of the three points of positive information within the prospect area and represents a starting point for a reanalysis. One of the most striking phenomena exhibited by the cross-section is the variation in surface elevation. It is possible that improper or incomplete corrections have been made. A look at the topographic map (Figure 5) shows a greater than average change in surface topography and that a related problem, if present, would not be confined to cross section A-A'.

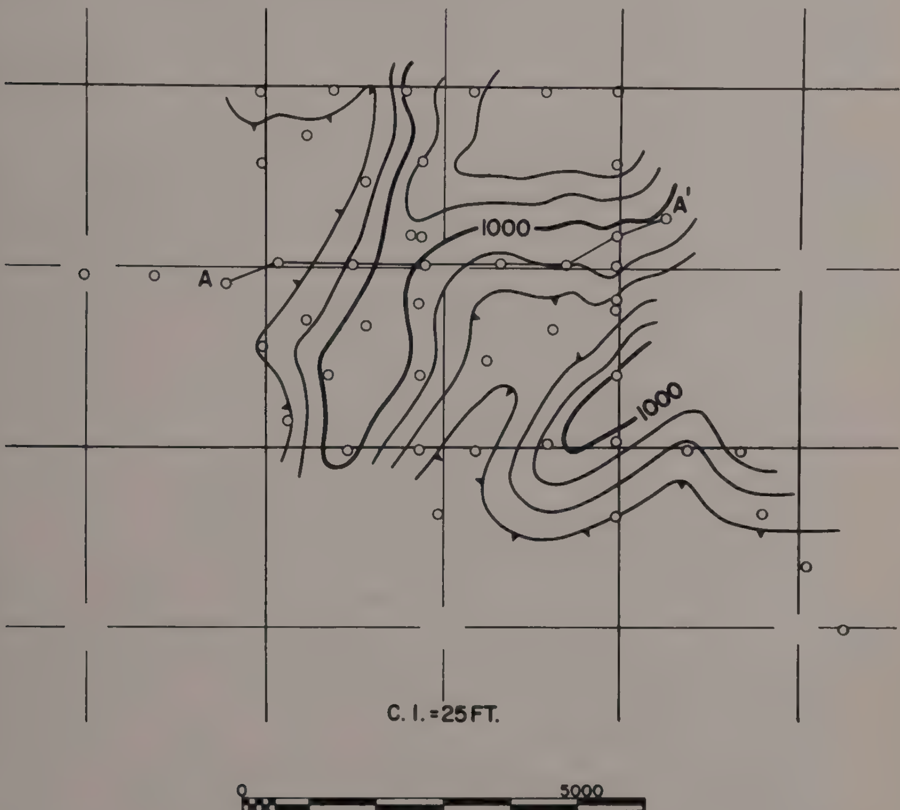


FIG. 5. Topographic map.

NEED FOR OVERBURDEN CORRECTION

A few articles have been published which deal with the relation of topography and velocity, or the effect of topographic overburden or depth of burial on velocity. Probably the most comprehensive article is that by M. B. Widess, (1946) "Effect of Surface Topography on Seismic Mapping". Mr. Widess reviewed the prior published material, made a mathematical treatment, and drew some very reasonable conclusions regarding other factors which are

associated with changes in topography. Field and laboratory observations by Haskell, by Faust and Weatherby, by Birch and Bancroft, and by Gutenberg, are reported on by Widess. They suggest that the effect of overburden (or depth of burial) on velocity results in an increase in velocity of roughly 0.4 to 0.5 ft/sec for each foot of increased overburden. However, the use of 0.5 ft/sec increase has, in the author's experience, accounted for only about one half of the differential observed on the average prospect. The increased differential may be the result of the effect of the lower elevations, and the secondary effect they yield by lowering the effective overall filter response of seismic amplifiers.

The last statement may need some clarification. Amplifiers behave as expected when subjected to laboratory signals. However, under field conditions the frequency and energy spectrum generated by the explosive charge must be considered. The end response shown on a seismic record is therefore a function of the energy and frequency spectrum generated by the shot as well as the filter response.

REANALYSIS USING OVERBURDEN CORRECTION

The simple sketch in Figure 6 illustrates the problem and the type of correction used to make an alternate interpretation. The basic conversion velocity was determined at the drill hole located at the A' end of the cross section A-A'. Records were time corrected to a "base-of-shot" datum and a conversion velocity for each shotpoint determined by an increment of increase or decrease in velocity of 1.0 ft/sec per foot of overburden as the surface elevation increased or decreased from that at the base point.

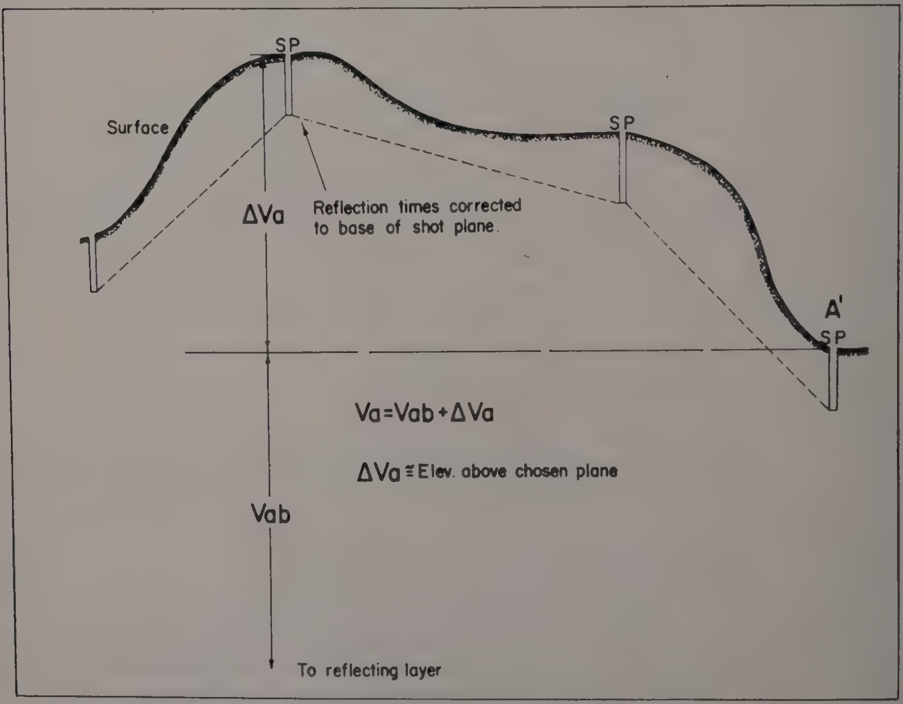


FIG. 6. Diagram of correction method used in reanalysis.

The alternate interpretation, determined by the use of a velocity varying with surface elevation, is shown by Figure 7. It may be noted that the feature

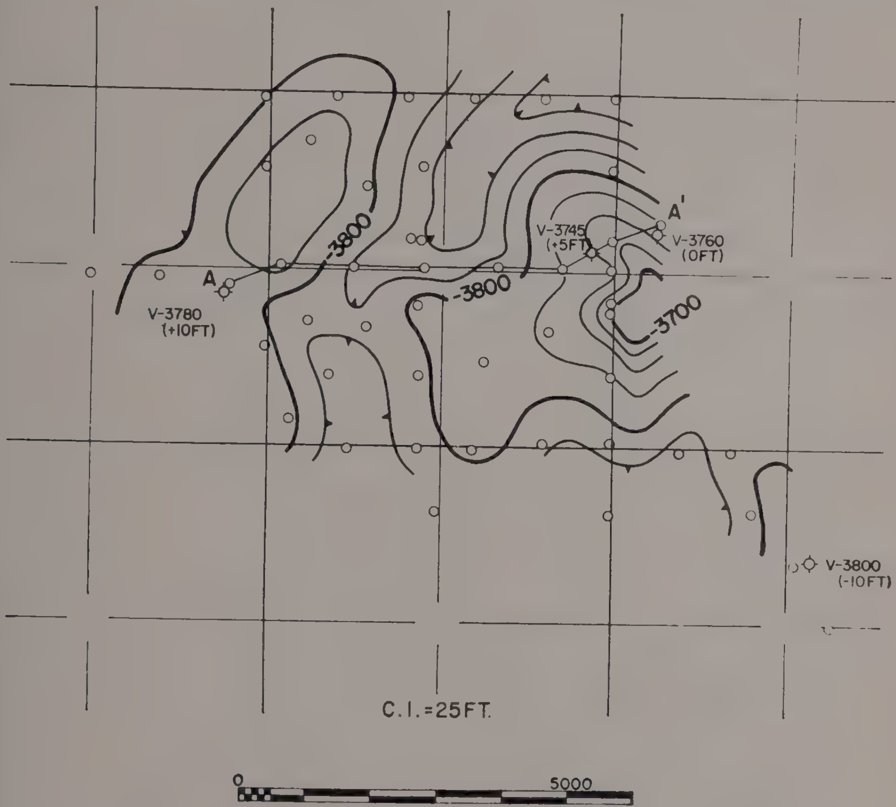


FIG. 7. Depth map of "Viola" reflection using velocity varying with surface elevation. Well ties are ±10 feet.

at the right side of the map is more pronounced than before and that the low relief structure in the central portion of the survey has vanished. Well mis-ties are now +10 feet, 0, and –10 feet against comparative figures of –30 feet, +30 feet, 0 feet obtained by the use of a constant velocity. We now have reworked the problem to obtain the answers furnished by well control.

So far in this dissertation the author has posed as an expert. Actually, the original interpretation (although the author had nothing to do with it) could have been his, or it could have been yours. Let us now be honest and see what the review interpreter had to work with in 1957. Figure 8 shows the well information plotted on the original interpretation while Figure 9 shows the same information plotted on the review interpretation. The old dry hole in the eastern part of cross section A-A' has been reworked into a producer; the pronounced feature at the east side of the prospect area is now an oil field; and the seismic structure in the central part of the prospect has been

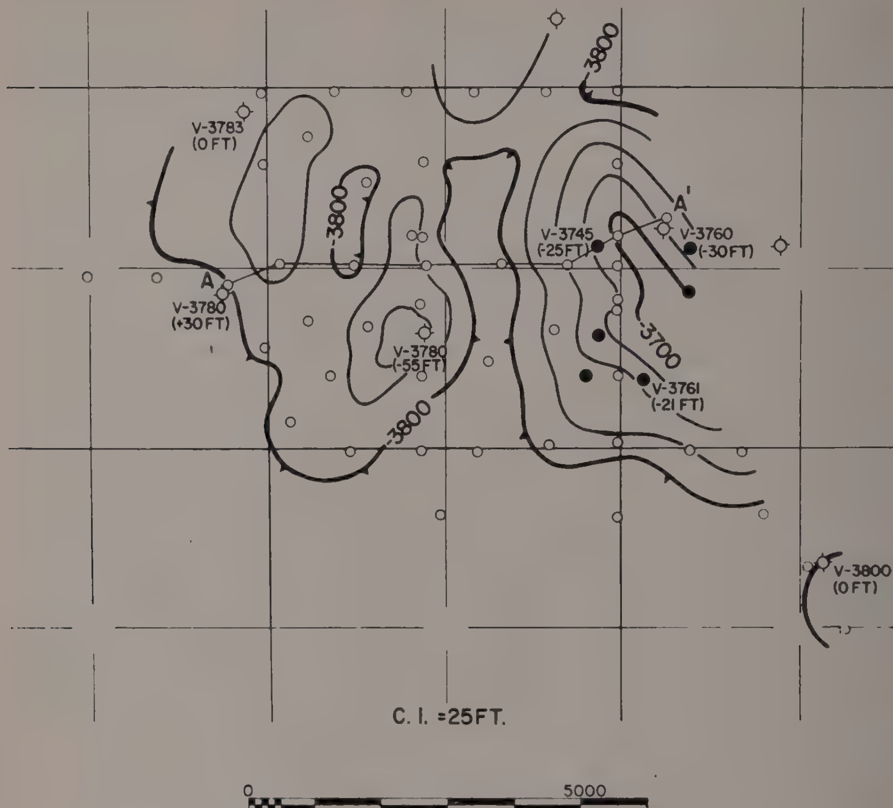


FIG. 8. Same as FIG. 3, with later well control added.
Note mistie of 55 feet on small central anomaly.

drilled and found to be absent. The wildcat on the last mentioned feature failed to check the original predicted depth by 55 feet (cause for reanalysis). The review interpreter had several more answers to guide him than did the original interpreter. However, most of the published information was available in 1949. If the measured observations revealed by these publications had been considered in making time conversions, the mis-ties of seismic data with the original three points of control would have been cut in half.

APPLICATION TO OTHER AREAS

A question which is certain to be in a reader's mind is "Have you observed this phenomenon in other areas and has the same approach yielded an apparent solution?" The answer is in the affirmative.

A number of years ago the author was involved in a survey which was conducted in an area which can be best described as an eroded plateau. Survey lines were of necessity along "ridge" and "valley" roads, with a normal elevation relief between such traverses of approximately 900 feet. Using normal correction methods, a seismic anticline was present under every ridge and a syncline under every valley. Fortunately well data proved this to be a false phenomenon. Through the use of some observed velocity information and the

process of elimination, the problem was isolated to velocity changes, or apparent velocity changes, varying with topographic elevation. The rate of change in velocity necessary to bring about a conformance of the seismic data with the established well control was 1.0 ft/sec. per foot of elevation change.

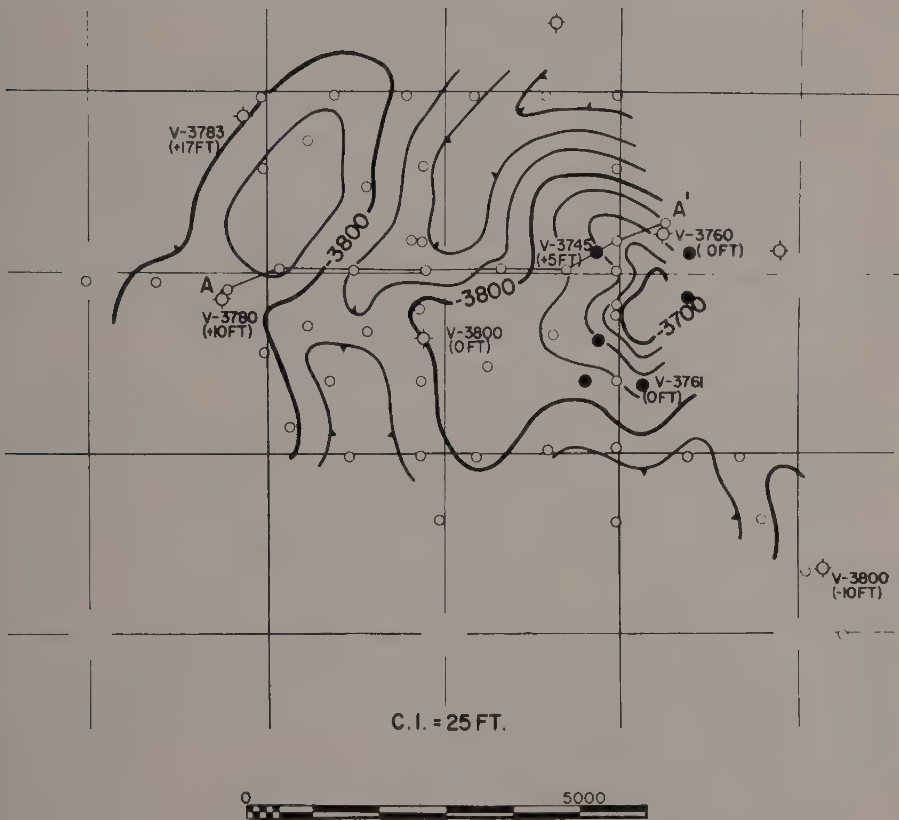


FIG. 9. Same as FIG. 7, with later well control added.

An example is available in published literature which can be tested. A very excellent paper "Topographic Effect on Near-Surface Velocities" by W. Baillie and T. Rozsa appeared in the October 1956 issue of GEOPHYSICS. Figures 1 and 4 of that publication are repeated herein with the consent of the authors and the SEG.

The left side of Figure 10 is a seismic time anomaly of an event stated by Baillie and Rozsa to originate "within the Lower Cretaceous section some 6000 feet below the surface" in the plains area of western Canada. The right side of Figure 10 shows the topographic relief over the same structure.

Core holes to depths exceeding 1500 feet were drilled at each of the five datum locations and the information obtained therefrom used to correct the time values to a datum plane 1400 feet above sea level or to a plane some 1500 feet below the surface. Figure 11 shows the time anomaly before and after correction for "load effect".

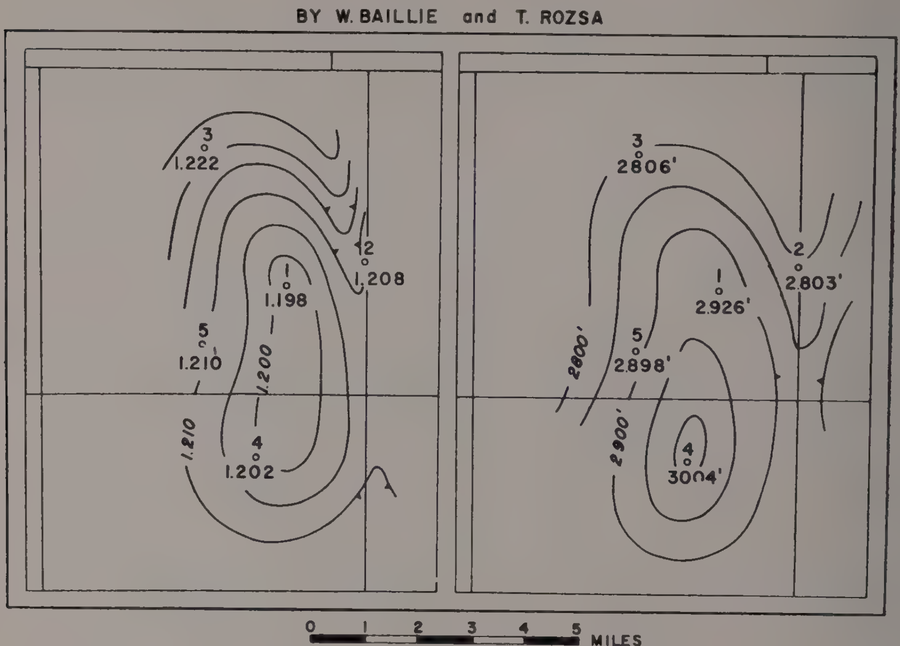


FIG. 10. Comparison of seismic anomaly with surface topography. (After Baillie and Rozsa.)

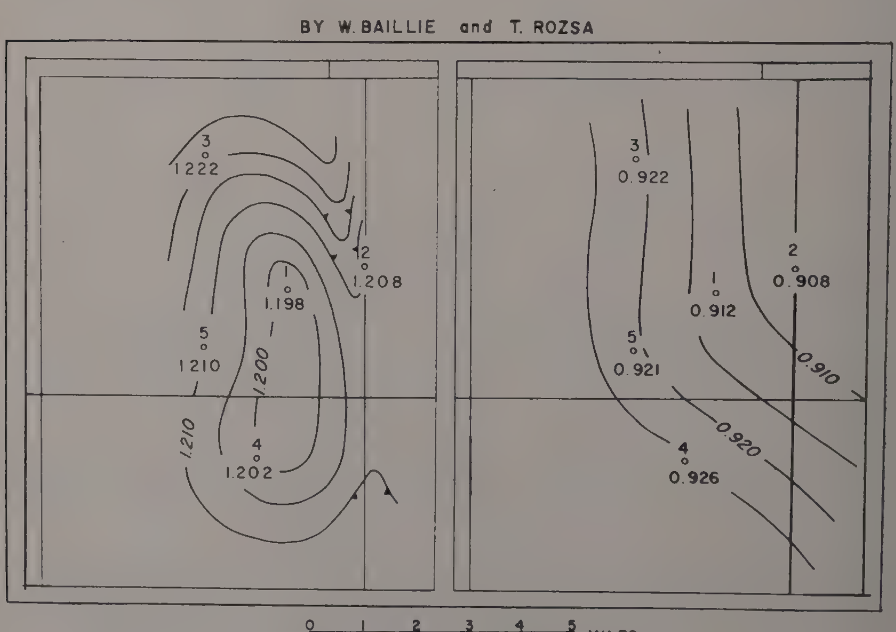


FIG. 11. Seismic anomaly before and after correcting for overburden effect. (After Baillie and Rozsa)

These same data were treated with the 1.0 ft/sec. per foot of overburden effect assumption and tabulated in Tables I and II. Time data and elevations are available in the Baillie and Rozsa article. The depth was estimated as 6000 feet for a time of 1.2 seconds, assuming 10,000 ft/sec as an approximate value for the average velocity.

Table I

Shotpoint	*Corrected Time*	*Assumed Velocity*	*Calculated Depth*
1	1.198	10,126 ft/sec	6065
2	1.208	10,003 ft/sec	6042
3	1.222	10,006 ft/sec	6114
4	1.202	10,204 ft/sec	6113
5	1.210	10,098 ft/sec	6109

Table II

			Depth Differential	
Shotpoint	*Time value after Load Correction*	*Calculated Depth at 1′/″/′ over-burden*	*Load Effect*	*Variable Velocity*
2	.908	6042	0	0
1	.912	6065	+20	+23
5	.921	6109	+65	+67
3	.922	6114	+70	+72
4	.926	6133	+90	+91

In Table I a velocity increment of 1.0 ft/sec. per foot of increased elevation over 2800 feet has been added to 10,000 ft/sec. to obtain a conversion velocity for each shotpoint (tabulated under the heading of "assumed velocity"). Those figures appearing in the column "Calculated Depth" are the resulting depths. In order to compare the results directly to those obtained by Baillie and Rozsa both sets of data must be reduced to either time or feet. In Table II the differences in the assumed depth obtained by converting the time differences at velocity of 10,000 ft/sec., or 5 feet per .001 sec. of increased time differential, are listed under "Depth Differential – Load Effect". The depth increment between the same points obtained by the use of a velocity varying at the rate of 1.0 ft/sec. per foot of elevation change are plotted in the next column under the heading of "Depth Differential – Variable Velocity". The agreement is extremely close.

CONCLUSIONS

The excellent results in these two recomputations are not intended to infer that the assumptions made herein are proven or that the same formula can be used on any other prospect with equal success. It can be stated with reasonable certainty however, that topographic overburden is a factor in velocity. One may also state with some certainty that topographic changes are associated with, and related to, a great many other time increment factors such as weathered layer thickness, weathered layer velocities, sub-weathered layer velocities, and changes in reflection frequency. In some instances these factors are of opposite algebraic sign and tend to cancel. In the majority of instances the author believes them to be additive and to result in a total

effect which is greater than that which can be attributed to increased overburden alone when based on any reported measurements.

General conclusions which can be drawn are as follows:

a) Topographic changes cannot be safely ignored if the magnitude of elevation change is equal to or greater than the order of magnitude of subsurface structural relief sought.

b) The time increment factors associated with topographic changes are additive in the majority of instances, resulting in an apparent topographic overburden effect which is greater than measured observations.

REFERENCES

Baillie, W. and Rozsà, T., 1956, Topographic effect on near-surface velocities: Geophysics, v. 21, p. 960-968.

Widess, M. B., 1946, Effect of surface topography on seismic mapping: Geophysics, v. 11, p. 362-372.

CORRELATION OF ADJACENT GRAVIMETER SURVEYS†

By

V. L. JONES‡

ABSTRACT

Gravity surveys conducted on adjacent areas at different times, by different personnel and with different gravimeters, often result in the two surveys not correlating properly at their common boundary. If the calibration for one instrument is incorrect, and the data obtained with this instrument are computed by using this calibration, the resulting contours are distorted along the common boundary of the two surveys. A corrected meter factor may be calculated for this gravimeter by extrapolating several profiles from the adjacent survey which was done with an instrument with acceptable calibration factor, into the area surveyed with the meter whose factor is faulty. This may be accomplished by means of an extrapolation formula derived by the author. A least-squares method for calculating the corrected meter factor is presented. The gravity values computed with this corrected factor will contour smoothly across the common boundary of the two surveys.

INTRODUCTION

In the preparation of gravity maps it is often found desirable to tie adjacent surveys, thus placing them on a common datum.

If the two surveys were conducted with different gravimeters by different personnel at different times, the contours of the surveys will, in general, not correlate properly at their common boundary.

If it can be established, or if it is reasonably suspected that the meter factor for one of the gravimeters is in error, due to a faulty calibration, or if it has changed since the instrument was calibrated, then this condition will result in the adjacent surveys not correlating properly, and in some cases the contours will be severely distorted along the common boundary of the two surveys.

Of course there are other errors which could result in a mis-tie of the contours at adjoining surveys. However, the problem to be considered in this paper will be the one that is due solely to an incorrect meter factor for one of the instruments, while the factor for the other instrument is assumed to be correct.

An ideal solution to the problem of course, would be to recalibrate the meter whose factor is thought to be in error. This is very seldom possible,

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‡Terrametric Exploration Co., Tulsa, Okla.

since the field work and computation of the data of one of the surveys were generally done long after the other survey was completed. Or the instrument used in the more recent work may have been removed to some remote area, and/or its factor may have since changed due to an unseasoned spring or other causes.

A solution to the problem may be had by extrapolation of the data from the survey whose meter factor is assumed correct into the area of the adjacent survey whose data were computed with the faulty meter factor.

THE PROBLEM

Let that portion adjacent to the common boundary of the two surveys which was worked with the meter whose factor is considered to be correct, be designated as area A, while that portion adjacent to the boundary which was worked with the meter whose factor is thought to be in error, be designated as area B. Also, let g_b denote the value of gravity at the primary base station to which the station values of both areas A and B have been referred. Further, let f_B denote the value of the incorrect meter factor which was used to compute the station values in area B, and let Δd_{Bi} denote the difference in dial divisions between the primary base station and the ith station (any station) close to the common boundary in area B. Finally, let g'_{3i} denote the computed value of this ith station.

Then,
$$g'_{3i} = g_b + \Delta d_{Bi} f_B \qquad (1)$$

A value for the ith station may also be calculated by extrapolating the data from area A into area B. This is accomplished by means of an extrapolation formula adaptable to desk calculators which was derived by the author*.

This formula is:
$$y_3 = y_0 - 3y_1 + 3y_2$$

where y_3 is the extrapolated value for an additional point along a gravity profile, and y_0, y_1 and y_2 are three equally spaced in-line values at the terminus of the profile. Thus, if we denote by g_{3i} this extrapolated value of the ith station, which is indicated by S in Figure 1, we may write

$$g_{3i} = g_{0i} - 3g_{1i} + 3g_{2i} \qquad (2)$$

Since in general there are many such profiles for which extrapolated values like that given in equation (2) may be had, it is possible to obtain a least-squares solution for a corrected meter factor.

If we denote by f_c a constant which, when added to f_B, would result in this corrected meter factor for area B, then we can also write

$$g''_{3i} = g_b + \Delta d_{Bi} (f_B + f_c) \qquad (3)$$

where g''_{3i} is the corrected value for the gravity of the ith station. Thus, it is possible to have three computed values for the gravity of S as indicated in Figure 1.

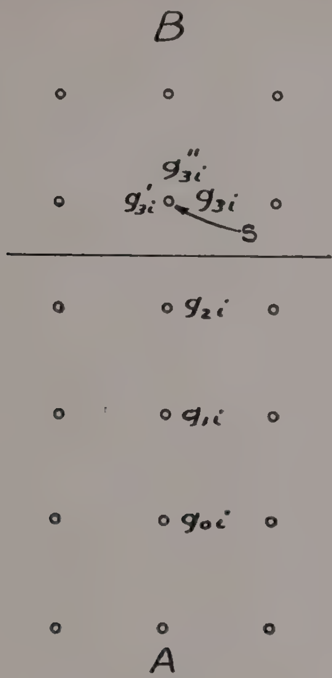

FIGURE 1

The difference between the extrapolated value and the corrected value, $g_{3i} - g''_{3i}$, is the residual, which can be obtained by substracting equation (3) from equation (2). Then, using equation (1) and setting the residual equal to zero we form the observation equation (4), as follows:

$$g_{3i} - g''_{3i} = g_{3i} - g'_{3i} - \triangle d_{Bi} f_c = 0$$

from which
$$g_{3i} - g'_{3i} = \triangle d_{Bi} f_c \tag{4}$$

Equation (4) is of the linear form, $y = bx$, and we normalize it in the usual manner, by multiplying through by $\triangle d_{Bi}$, the coefficient of the unknown f_c.

$$\triangle d_{Bi}(g_{3i} - g'_{3i}) = (\triangle d_{Bi})^2 f_c \tag{5}$$

Summing equations (5) for all of the values obtained from the many available profiles between areas A and B, we have

$$\Sigma \triangle d_{Bi}(g_{3i} - g'_{3i}) = \Sigma(\triangle d_{Bi})^2 f_c \tag{6}$$

from which
$$f_c = \frac{\Sigma \triangle d_{Bi}(g_{3i} - g'_{3i})}{\Sigma(\triangle d_{Bi})^2} \tag{7}$$

Equation (7) thus permits a least-squares solution for f_c, and its value may be calculated.

The work sheet for the computation of f_c will contain a minimum of four columns, one each for $\triangle d_{Bi}$, $(\triangle d_{Bi})^2$, $(g_{3i} - g'_{3i})$ and $\triangle d_{Bi}(g_{3i} - g'_{3i})$.

If the station spacing at the common boundary of the surveys does not permit equally spaced in-line points as illustrated in Figure 1 and the examples which follow, then equally spaced in-line points across the boundary may be

computed by means of one of the several interpolation formulae derived by the author*.

EXAMPLES OF THE TECHNIQUE

The map illustrated in Figure 2 is taken from a portion of two adjacent gravity surveys which had a common boundary indicated by the vertical

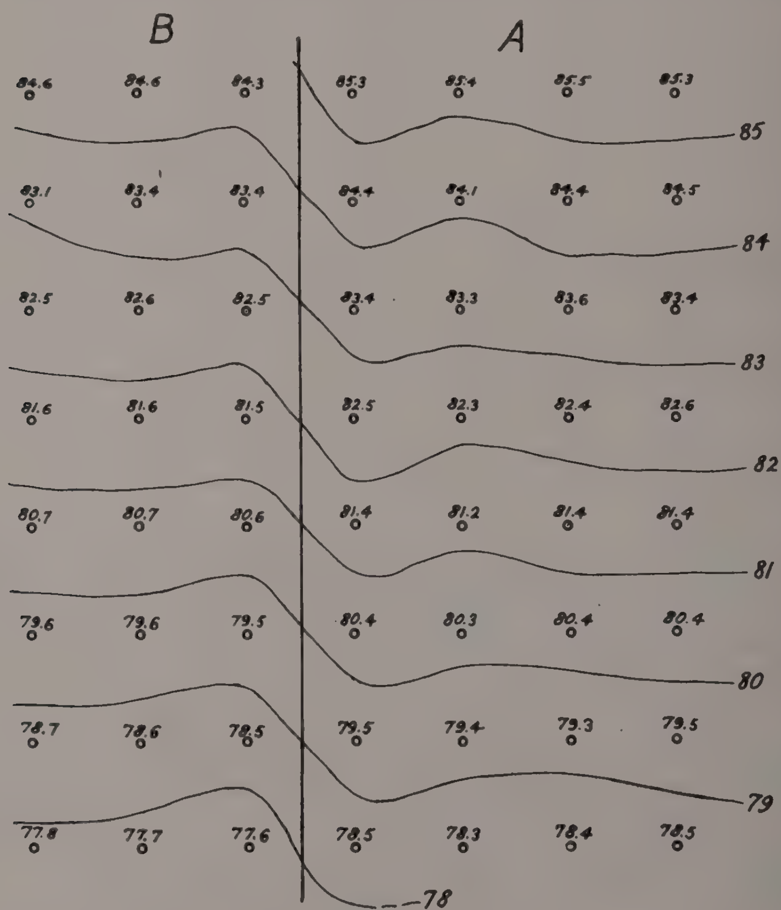

FIGURE 2

line. After the data for survey B were computed and contoured, the severe distortion along the boundary resulted. It was immediately recognized that the meter factor for the instrument used in survey B was in error. This recognition was justified by the fact that it was a new instrument with an unseasoned spring and it had received several severe jolts while in transit to the survey area.

After the above technique was employed to obtain a corrected meter factor, the survey data in area B were recomputed and the contour values for the points redetermined. The results are shown in Figure 3. It will be noted that the data now contour smoothly across the boundary of the two surveys. It will also be noted that the low nosing in survey A which is somewhat distorted

in Figure 2, is now more clearly defined in Figure 3. Of course it is not possible to make a quantitative determination of the improvement affected in the corrected meter factor for the case like that illustrated in Figures 2 and 3. However, the degree of improvement can be estimated approximately.

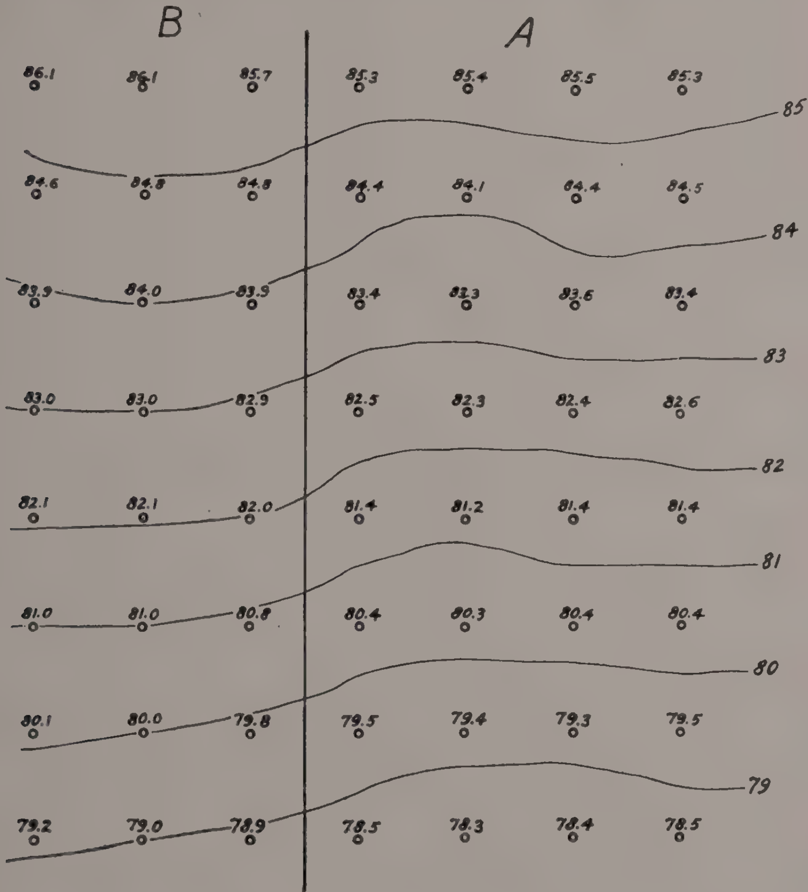

FIGURE 3

In order to obtain some quantitative information relative to the percentage of improvement that results from a corrected meter factor, the following illustration was selected. Figure 4 shows a portion of another gravity survey which was conducted with the same meter throughout. An arbitrary phantom boundary was established as indicated in Figures 5 and 6. Then, the meter factor was changed in such a manner that it contained an error of 8.24%. The survey data in area B were recomputed with this meter factor containing the error. The results are shown in Figure 5.

It will be noted that while the contours are not as severely distorted as in the example illustrated in Figure 2, they do depict anomalous features at the boundary which in some cases might provoke an over zealous interpreter to turn to his second derivative or residual methods for an interpretation. Anomalous features at the boundary of two adjacent surveys which

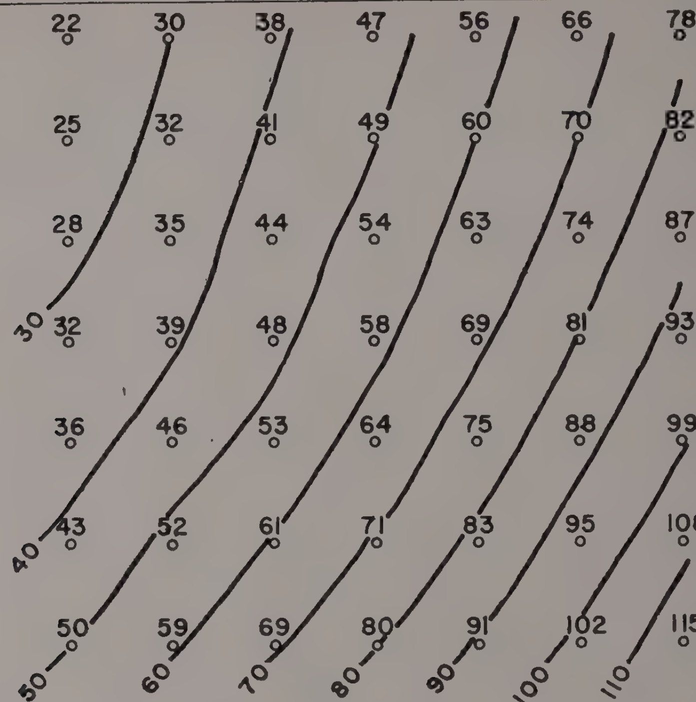

FIGURE 4

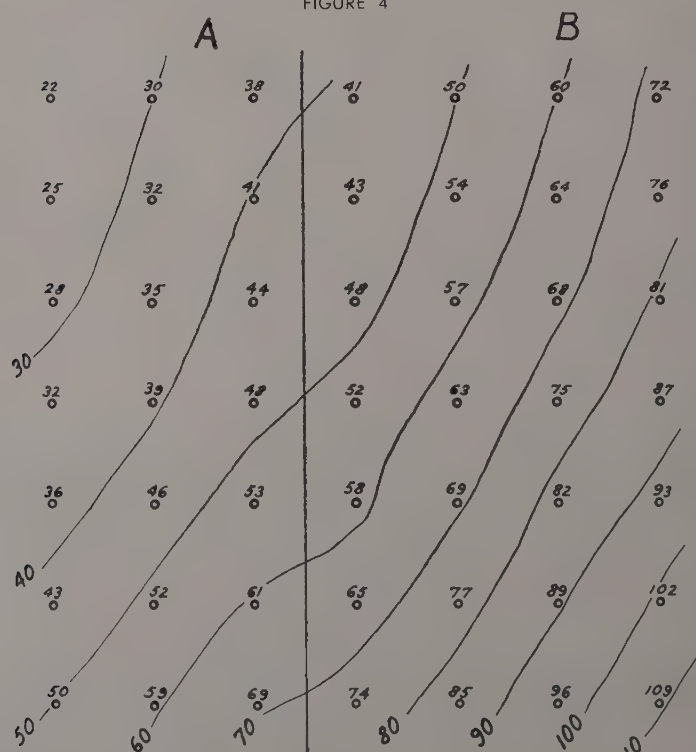

FIGURE 5

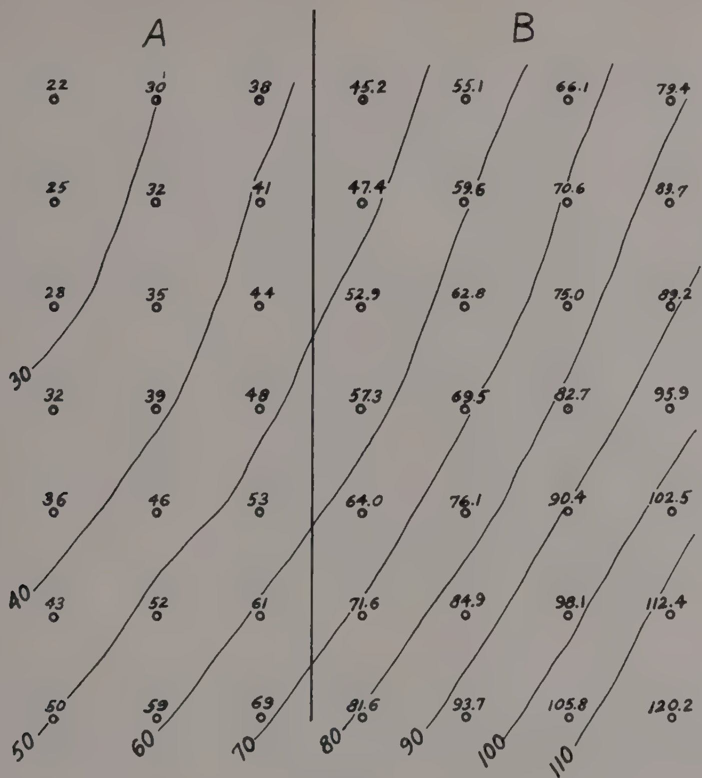

FIGURE 6

have been placed on a common datum should, therefore, always be questioned. The present of these anomalies and lack of severe distortion as in Figure 2, are due to the orientation of the phantom boundary with respect to the gradient of the gravity field as shown by the data.

When the above technique was applied to the data in area B of Figure 5, a corrected meter factor was obtained which, was found to have an error of only 1.13% with respect to the original meter factor used in computing the data of Figure 4. This is an improvement of a little over seven to one, or a diminution in the meter factor error of 86.28%. The results obtained with this corrected meter factor for area B are shown in Figure 6.

It is to be noted that the overall picture presented by the contours of Figure 6 bears a striking resemblance to the original of Figure 4. The anomalous features at the phantom boundary have disappeared, and there are no anomalous conditions or features not present in the original data of Figure 4. The technique would thus have been justified had there been two adjacent surveys with a real common boundary instead of the phantom boundary used for illustration purposes.

REFERENCE

° Jones, V. L., 1956, Extrapolation and Interpolation Formulae Adaptable to Desk and and Other Types of Digital Computers: Geophysics, v. 21, p. 1047-1054.

THE SEISMOD RECORD SECTION

By

A. C. Reid*

There have been many and varied types of seismic displays developed since the advent of magnetic recording. Sinclair has recently developed and applied for patents on a method of producing seismic displays on record sections, which have some of the visual qualities of variable density sections, and yet retain seismic wave form character.

The Seismod,[1] as the name implies, uses the output signal from conventional seismic amplifiers to amplitude modulate a carrier frequency. The output of the modulators drive conventional seismic galvanometers and normal photographic recording procedures are used. The carrier frequency of 1200 cps is high enough to expose the film in a smooth envelope, and at this frequency no difficulty is experienced in driving the galvanometers to the desired amplitude. The seismic signal to the modulators is adjusted to permit 100% modulation on the strongest signals, with the peaks permitting approximately twice the normal carrier amplitude and the trough restraining the normal carrier amplitude.

Figures 1 and 2 display the same portion of a record section; Figure 1 by Seismod and Figure 2 by conventional galvanometer trace. No static or dynamic corrections were made. No mixing between traces was performed.

The magnetic tapes used in producing the illustrations are from the vicinity of an off-shore salt dome. The lower part of both presentations shows steep dip characteristic of salt domes.

Because of its recent development, the Seismod presentation has not been used extensively in field work. However, some interpreters who have worked with it believe that it is easier to identify and correlate Seismod wave forms than conventional galvanometer wave forms. This advantage of the Seismod display is due to the ability of the human eye to compare similar areas of the modulated signal envelope more readily than similar portions of conventional traces. This improved perception gives meaning to the variously shaped "beads", "spools", and "dumbbells" of the modulated display. This may, perhaps, help to define horizons which do not give rise to reflections of major amplitude and may be of assistance in the detection of faults, pinchouts, and sedimentary lenses.

*Sinclair Research Laboratories, Inc., Tulsa, Oklahoma

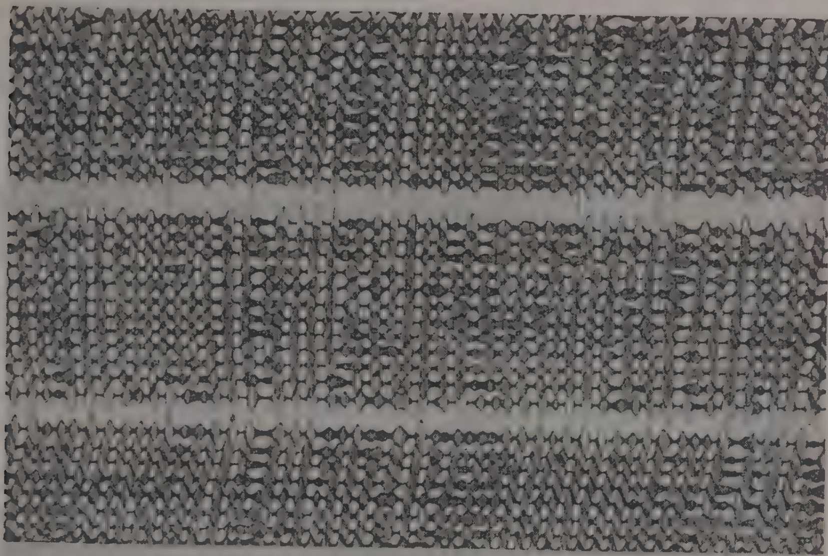

Figure 1 Seismod Record Section Display

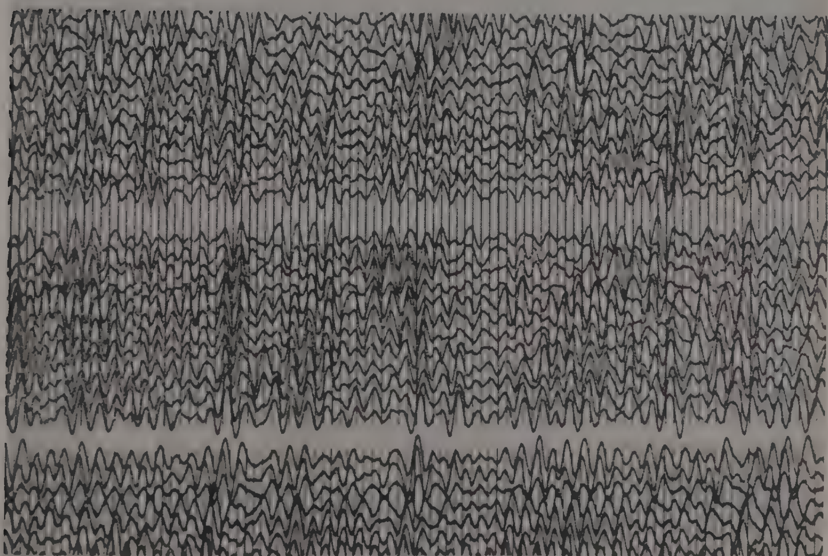

Figure 2 Conventional Record Section Display

ABSTRACTS OF PAPERS AND LECTURES GIVEN BEFORE THE GEOPHYSICAL SOCIETY OF TULSA
1957-58

RECIPE FOR RESEARCH

by

JOHN M. CRAWFORD
Continental Oil Company
October 10, 1957

The director of a research group in exploration encounters many problems. Some of them can be anticipated, but the rules which apply for management of most business organizations may not succeed.

AN ELECTRONIC SEISMIC DIP PLOTTER

by

JAMES A. WESTPHAL
Sinclair Research Laboratories, Inc.
October 10, 1957

The paper describes an electro-mechanical dip migrating machine which rapidly and accurately plots, in either time or depth, migrated dip segments obtained directly from conventional seismograms. This machine was designed to fill the need for the rapid construction of migrated dip sections from the very large number of records obtained in surveys in the offshore waters of Louisiana and Texas. Although at the present time reconnaissance shooting has been largely completed in these offshore areas, the machine has proven very useful in detailed seismic reinterpretation.

SEISMOLOGY AND THE EARTH'S DEEP INTERIOR

by

DR. K. E. BULLEN
SEG Distinguished Lecturer, University of Sydney, Australia
October 29, 1957

The paper covers the use of seismic data to chart the earth's interior broadly into eight regions; the application of seismic data to determine the earth's distribution of density, pressure, gravity, compressibility and rigidity; and the evidence for the solidity of the inner core.

SYNTHETIC SEISMIC REFLECTION STUDIES

by

H. R. BRECK, NOEL FROST AND S. W. SCHOELLHORN
Seismograph Service Corporation
December 12, 1957

Synthetic reflection records derived from continuous velocity logs are of particular value in the identification of seismic reflecting horizons. Field techniques in shooting seismic prospects can be guided by synthetic record studies. These studies promise to be the key to the detection of stratigraphic traps. The character of a reflection is rarely determined by a single interface

but rather by the interaction of a number of interfaces. Manifestations on the seismic records of pinchouts, facies and porosity changes are controlled by the intervals between the interfaces as well as by the velocity contrast between the formations. Stratigraphic changes whose reflecting characteristics lie within the seismic frequency spectrum can be identified through the use of synthetic seismograms.

OPERATION MOONWATCH

by
James A. Westphal
December 12, 1957

Mr. Westphal discussed the objectives and procedures of the IGY artificial satellite tracking program. Techniques employed by the Tulsa "moonwatch team" to obtain accurate data were illustrated.

MODERN CONCEPTS IN REFLECTION SEISMOLOGY

by
Dr. F. A. VanMelle
Shell Oil Company
January 9, 1958

The paper attempts to illustrate the sort of things seismologists are looking at as the seismic method approaches maturity. It is by no means a comprehensive account of recent advances in seismology, but by necessity puts a rather one-sided emphasis on studies with which the speaker is familiar.

THE INTERNATIONAL GEOPHYSICAL YEAR

by
Paul L. Lyons
Sinclair Oil and Gas Company
February 13, 1958

The International Geophysical Year will write a ticket to the future of our exploration of the earth, the sun, and the moon. Another result of the researches will undoubtedly be the tapping of new sources of energy. Among the immediate, tangible results interesting to exploration geophysicists will be the data on Antarctica. The odds favor the chances that the polar continent will contain deposits of hydrocarbons and minerals which can be found by careful exploration. It is quite likely that complete gravity and magnetic maps of the entire earth will be available as a result of the observations made during the IGY. Perhaps the most fascinating inquiry will be that into the nature of time itself. Two types of time, gravitational and atomic, will be compared. Cosmic rays will receive their share of study. Vast amounts of chemical energy have been found to reside in the components of the upper atmosphere, so that aircraft or rockets in that medium have available free fuel to drive them. A ten million ampere ring of current has been found surrounding the earth at high altitude. The puzzling warming of the seas and climate will be investigated. The most spectacular observations will be those made by rockets and artificial satellites, and some of the results will have a direct bearing on exploration geophysics. The satellites put into orbit, and those which reach the moon, will be the ultimate in geophysical instrumentation.

AN EMPIRICAL VELOCITY DETERMINATION IN SOUTHERN OKLAHOMA

by

Donald R. Oksa
Sinclair Research Laboratories, Inc.
February 13, 1958

Lack of adequate velocity data can sometimes be overcome by the proper coordination of seismic and geologic factors. The basic assumption that seismic and geologic data are directly correlatable must be utilized to its fullest extent. Upon this basis reliable basic seismic data of time and $\triangle t$ values are computed with variations in the other parameters to make the computed seismic data closely match the known geologic conditions by one of several standard computing methods. The empirical fitting of the seismic data to match geologic conditions establishes the velocity gradient which can then be extrapolated into immediately adjacent areas. An iso-velocity section can also be prepared, if desired. Generally, it appears that iso-velocity contours parallel formational strikes.

The application of empirically derived velocity data results in seismic structural maps and cross-sections which are compatible with actual geologic conditions. The value of the oftentimes neglected "true dip" section is shown and is actually an integral part of the analysis. The application of electronic computing techniques makes such determinations much more rapid and makes the method entirely feasible.

RESOLUTION OF GRAVITY ANOMALIES

by

E. V. McCollum
E. V. McCollum and Company
March 13, 1958

Anomalous mass may be estimated by computing the flux of gravity through the earth's surface. When the calculations are made at a number of points on the earth's surface, the values may be placed on a map and contoured. The resulting picture tends to resolve local gravity anomalies and subdue regional effects. In favorable situations the causative mass may be approximated. In less favorable cases the anomalous mass aids in placing depth ranges on the disturbing mass.

SEISMOGRAPHING WITH A VIBRATOR

by

John M. Crawford and W. E. N. Doty
Continental Oil Company
April 10, 1958

A new approach to seismic exploration is being tried. Instead of explosives or a falling weight, the energy is generated by a vibrator. The basic principle is described and sample records shown. Photographs of equipment are included in the presentation.

POINT PLOTTING USING ELECTRONIC COMPUTERS

by
C. A. Wood
Shell Oil Company
May 8, 1958

This paper describes a system for point plotting seismic cross sections, using a digital computer and a modified IBM type 407 accounting machine. The computer computes corrections to datum for each trace, corrects the reflection times and plots the cross-sections. Also, corrections are computed for normal stepout. The scale of the final cross-section is 1″ = 400′.

The time required to prepare cross-sections using the electronic computer is slightly greater than the time used in plotting sections by hand methods. This difference can probably be reduced by using short cuts in the preparation of data for the machine computations. The advantages of the system are (1) computing and plotting accuracy are improved, (2) isopachous cross sections can be made with relative ease, (3) after basic data have been read and punched, additional cross-sections plotted with different datum, correction velocity, or velocity distribution can be plotted with relative ease. This technique may be useful in special studies which involve problems that may be resolved through the use of interval cross-sections, or in areas where it is important to study the effect of changing velocities.

THE SEISVERTER

by
Edward J. Crossland and Dr. James E. Hawkins
Seismograph Service Corporation
May 8, 1958

A device for converting ordinary field seismograms into corrected magnetic tapes or directly into corrected variable density cross-sections is described. Its capabilities for altering, filtering, mixing, and shot compositing, and its capabilities for applying weathering, elevation, and normal move-out corrections are presented. Tracking arrangement, magnetic type and variable density film sizes and speeds, and provisions for correcting speed variations are described.

ABSTRACTS OF PAPERS AND LECTURES GIVEN BEFORE OTHER LOCAL SECTIONS OF SEG, 1957-58

HOUSTON GEOPHYSICAL SOCIETY

Chartered February 14, 1948

Seismology and the earth's deep interior

DR. K. E. BULLEN
For abstract see p. 52

The key variables of gravity

FREDERICK ROMBERG, Geophysical Service, Inc., Houston, Texas

There is an inherent difficulty in converting gravity data into geologic information because the problems have to be solved indirectly. This difficulty has given rise to an intellectual gap between people who interpret gravity data and those who apply the results. With a view to bridging this gap a check list of variables important to the correlation of gravity and geology is offered. This should help the non-specialist get a better

idea of where gravity will give him useful information. Remarks are made on the role each variable plays in the interpretation process and on the accuracy with which each may be used in computations. The effect of target depth on residual and derivative interpretation methods is examined. Examples are given showing the extent to which information about geologic structures can be got from gravity.

The use of geophysics in the development department

PETER B. BIKE, Seaboard Oil Company, Dallas, Texas

The development, or exploitation, department has attained a significant and integral status in many oil companies. Development formerly directed by the exploration and production personnel has evolved into a separate department staffed by geologists specializing in this field.

A case history of the Encino Field, San Patricio County, Texas, is discussed to illustrate how both exploration and development geophysics were applied successfully to a geological concept in the discovery and development of an oil field.

After completion of the discovery well, normal development ensued to the No. 9 test which was a dry hole. Geophysical data, previously obtained, was integrated into the then known complexities of the subsurface with additional success. A continuous re-evaluation of both subsurface and geophysical data was made. Subsequent seismic development program was conducted and the data were again composited.

The results indicate the value of and need for geophysical personnel with geological experience in the development department.

Geophysics and geopolitics

PAUL L. LYONS, Sinclair Oil & Gas Co. and
BEN F. RUMMERFIELD, Century Geophysical Corp.

A vast pool of technical ability and equipment is presently available for world wide usage in discovering petroleum reserves. This commodity is highly perishable, and it primarily depends upon proper incentive to survive. By "proper incentive" is meant a political and economic climate conducive to the employment of risk capital and thinking, without which oil cannot be found.

Whereas there is room for government-controlled exploration, the facts based upon world wide experience, give a tremendous advantage to the operations of private enterprise. Bureaucracies by nature are not suited to the risk aspect and tempo of the oil business.

Unless world wide exploration is properly stimulated by the withdrawal of political handicaps, domestic and foreign, not only will our technical assets wither, but also it is possible that world wide oil and gas reserves themselves will be wasted by simply not being found. No longer can a country afford to withhold oil prospects for the future. The countries that do will run a grave risk of competing with other sources of energy, such as atomic and solar, in the future.

Scale in exploration

O. C. CLIFFORD, JR., The Atlantic Refining Co.

"Scale" must be chosen with respect to the exploratory problem. When the derivation of the solution involves data of different units, a common and compatible unit must be found. This is as true of scale for economic problems in petroleum exploration as for technical problems. Examples from each field are given to show that the correct choice of scale will aid in the analysis of either problem.

The results of the gravity and seismic program of the IGY

DR. G. P. WOOLLARD, University of Wisconsin

Abstract not received.

PACIFIC COAST SECTION SEG

Chartered April 12, 1948

Papers given before the Local Section at the annual fall meeting in Los Angeles, November 7-8, 1957

Comparison of seismogram cross-sections recorded in various modes

F. S. KRAMER, O. W. SCHOENBERG and R. A. PETERSON, United Geophysical Corp.

A comparative study of a variety of modes of seismogram presentation is illustrated by a series of cross-sections. The cross-sections are photographically recorded by repetitive play backs of field magnetic tapes.

An electronic seismic dip plotter

JAMES A. WESTPHAL, Sinclair Research Laboratories, Inc.

For abstract see p. 52

Descriptive geometry and the offset seismic profile

JOHN P. GATES, Western Gulf Oil Company

For complete paper see GEOPHYSICS, v. 22, p. 589-609

An illusion is created in attempting to portray steeply dipping seismic data by standardized geometric procedures. The offset seismic profile, although resembling the vertical geologic cross-section in appearance, may have an inherent tilt which is a function of cross dip. Unless this tilt is accounted for during the solution of critical structural problems, serious errors can enter into the interpretation of the seismic data. Descriptive geometry procedures are applied to establish the tilt and determine its effect on fault traces, structural axes, and well ties.

A comparative study of measured and theoretical gravity anomalies

STEPHEN W. DANA, University of Redlands

A trip was made to Indiana in the summer of 1949 for the purpose of collecting data for a comparison between the measured gravity anomaly of a typical coral reef oil field and the theoretical gravity anomaly calculated for that same field. In order to treat the problem in three dimensional terms, the densities of available core samples from the field were determined, and the anomaly was calculated taking into account the variation of density horizontally and vertically. This also required taking into account the geologic structure of the field based upon core studies and electrolog data.

A comparison of the theoretical and actual anomalies indicated a rough correspondence except for several sharp negative anomalies on the flanks of the measured gravity anomaly. In order to explain the negative anomalies, further studies were made which indicate that these are possibly due to shallow river erosion channels on the surface of the youngest sediments (Pennsylvanian) that were filled in with glacial till.

An aeromagnetic study of the Copper River Basin, Alaska

GORDON ANDREASEN, ISIDORE ZIETZ and ARTHUR GRANTZ, U.S.G.S.

An aeromagnetic survey was made of approximately 6,000 square miles of the Copper River Basin, Alaska, in 1954 and 1955. North-south flight lines spaced one mile apart were flown from latitude 61°45' to 63°00'. The eastern and western borders of the surveyed areas are at longitudes 145°00' and 147°22'.

The magnetic patterns closely parallel the generally east-west arcuate geologic "grain" and seem to correlate with lithology and with geologic structure. Outcropping areas of volcanic rocks are reflected by the configuration of the magnetic contours. A large area of low-amplitude magnetic anomalies extends from the Chugach Mountains north to about latitude 62°30'. This area may possibly outline a structural basin of Tertiary age superimposed upon a depositional and structural trough of Jurassic and Cretaceous age.

Anomaly-producing rock masses within this area are estimated to be a mile or more beneath the surface and are interpreted to be most deeply buried beneath the southern part of the Copper River Basin.

The magnetic data suggest that lower Jurassic volcanic rocks exposed in the Talkeetna and Chugach Mountains underlie the marine and nonmarine sedimentary rocks of the southwestern part of the surveyed area. The change in the magnetic pattern at the northern front of the Chugach Mountains is caused by a contact between these volcanic rocks and the younger sedimentary rocks to the north. The magnetic data suggest that the Wrangell lavas of Tertiary and Quarternary age are present at shallow depths beneath the basin in the vicinity of Mount Drum.

An aeromagnetic reconnaissance of the Cook Inlet area, Alaska

GORDEN ANDREASEN, ISIDORE ZIETZ, and ARTHUR GRANTZ, U.S.G.S.

Fourteen aeromagnetic profiles were flown east-west across the Cook Inlet area in 1954, nine extending from about the Triumvirate and Capps Glaciers to the Chugach Mountains, and five from the Iniskin-Chinitna Peninsula to the Kenai Peninsula. These profiles show several magnetic features that seem to have geologic significance.

The overall arched character of the profiles suggests the existence of a block-shaped rock mass underlying Cook Inlet at great depth. A 1,600-gamma anomaly was observed over Mt. Susitna, a granitic intrusion. A two-dimensional anomaly observed over Knik Arm may reasonably be attributed to a zone of buried granitic intrusive rocks continuous with the intrusive cropping out at Eklutna. This intrusive, or zone of intrusives, appears to deepen to the south, reaching estimated depths of 5,000 or 6,000 feet at the lower end of Knik Arm. Anomalies observed over the Susitna flats indicate that the magnetic basement is buried some 12,000 to 14,000 feet.

An abrupt magnetic rise of 300 to 400 gammas observed over the coast line of the Iniskin-Chinitna Peninsula is caused by a significant change in rock type, suggesting the possible existence of a fault with a vertical displacement of several thousands of feet. East of this area, no near-surface anomaly-producing rock masses are present. It is likely that here the depth to magnetic basement is very great.

Gravity exploration

RAOUL VAJK, Standard Oil Company (N. J.)

The relation that exists between the gravity field of the earth and the various properties of the earth, its geology and the mineral deposits is described. The instruments and methods used for investigating the gravity field of the earth and its anomalies are discussed, and, finally, the methods of interpreting the gravity anomalies, that is, the methods of determining the objectives of gravity exploration, are critically reviewed.

Papers given before the Local Section at the annual spring meeting in Bakersfield, April 15, 1958

Analog computers and attraction problems in gravity

FREDERICK ROMBERG, Geophysical Service, Inc.

The importance to gravity exploration of solving problems in gravitational attraction is examined. The usefulness of such problems in different phases of oil prospecting is discussed, with particular reference to the limits of accuracy which exist. The role of numerical and analog computations in solving attraction problems is demonstrated by means of examples, showing where time can be saved, and interpretation broadened, by analog computers.

An optical analog gravity computer

R. W. BALTOSSER, Seismograph Service Corp.

The SSC Optical Analog Gravity Computer is an instrument which indicates the simulated gravity values of a geologic model. The models are made by sketching to scale sections which represent the earth's densities. When the model is examined in the instrument, the readings simulate gravity values. These simulated gravity values may then be compared to Bouguer gravity values taken from an actual survey.

The geologic sections are prepared in a conventional manner with shading controlling the simulated densities. The models can be easily modified by changing the shading and the resulting gravity values quickly redetermined.

Both two and three-dimensional models may be examined with the choice of several scale ratios.

The theory of the instrument is described and its limitations and possibilities discussed. Examples of gravity profiles from local and typical cross-sections are shown.

Seismic trace section plotter for production operation

W. W. KLEIN, JR., California Research Corporation

There has been a major need for a suitable seismic trace section plotter to function directly with a production playback office analysis system. Such a unit has been developed and is now operating on a production basis.

The major features of the instrument are accuracy, speed of operation, and versatility. The machine plots directly from magnetic tape in true time at a production rate limited primarily by the time required to change tapes on the magnetic tape reproduce drum. Continuous sections of essentially unlimited subsurface coverage may be plotted in a routine manner. Either time or depth sections may be plotted, and the data may be displayed in conventional oscillographic, variable area, or variable density form.

Seismic operation in Cuba and Jamaica

CARL SAVIT, Western Geophysical Company

Cuba and Jamaica, the westermost islands of the Greater Antilles, comprise a zone of exploration of unparalleled variety. Sediments from Lower Cretaceous to Miocene and Recent overlie a fantastically complex basement composed of a great variety of highly faulted and deformed metamorphic and igneous rocks. Among the situations encountered are near-surface cavernous limestones, reefs, multiple overthrust sheets, and even virtually undisturbed basins. Reflection quality ranges from excellent to "no record". Several geologic sections and seismic record sections are presented.

Some aspects of seismic operations in the Cook Inlet area, Alaska

NOLEN WEBB, Richfield Oil Corporation

During the summer months of 1955, Richfield Oil Corporation tested the following types of seismic operations in the Cook Inlet area of Alaska:

1. Marine seismic methods. 2. Upland portable seismic methods. Some of the methods used in these operations are discussed as well as some problems peculiar to the area.

Exploration

GRAHAM B. MOODY, Consultant, San Francisco

Abstract not received.

Determining the reliability of magnetic surveys as reflections of geology

WAYNE HOYLMAN, Consultant, Los Angeles

This paper discusses the differences between the sensitivity and the reliability of magnetic surveys (ground and airborne). Surveys sensitive to plus or minus 1.0 gamma may not be reliable to within plus or minus 10.0 gammas. Airborne data with a sensitivity of plus or minus 1.0 gamma have a survey reliability determined by two conditions: 1. Accuracy of horizontal control. 2. Behavior of diurnal variation.

A recent study of this latter condition, using the Varian magnetometer, has shown that diurnal variation is causing a more serious decrease in the reliability of surveys than was formerly suspected.

Paleomagnetism

DR. S. K. RUNCORN, Kings College, England
AAPG-SEG Distinguished Lecturer

Many igneous and sedimentary rocks have been shown to possess remanent magnetisation. The direction of this magnetisation can often be shown to have changed little since early in the history of the rock. The directions of magnetisation of such "stable" rocks in one continent vary greatly through the geological column. If it is assumed that on the average the geomagnetic field is a dipole then the directions of magnetisation may be represented by a slow motion of the dipole axis relative to the sampling site through geological time. It has been found that there are significant discrepancies between the paths deduced from measurements in the different continents, and this is thought to show that continental drift has occurred.

Theory and observation alike suggest that the magnetic axis of the earth when averaged over times longer than a few thousand years coincides with the axis of rotation. Therefore there appears to have been considerable polar wandering at a roughly constant rate through geological time. Some comparison between the palaeomagnetic results and palaeoclimatic evidence is possible.

The geological applications of rock magnetism and the geophysical implications of the results will be discussed.

DALLAS GEOPHYSICAL SOCIETY

Chartered August 7, 1948

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

The role of gravity in orogenesis

DR. WALTER H. BUCHER, Columbia University

Gravity experiments using models are described.

A hypothetical view of the role of gravity in orogenesis is summed up as follows:

1. It creates a state of all-sided compression in the outermost shell of the earth, the stereosphere, as the latter adjusts itself to the loss of volume in the underlying shrinking shell of the outer mantle, the strictosphere.

2. It achieves crustal shortening by compressing into orogenic welts the relatively narrow zones along which hot gaseous emanations weaken the stereosphere, escaping upward from great depths along oblique fracture zones marked by deep-focus earthquakes.

3. As the orogenic welts rise to elevations greater than can be supported by the strength of the rocks, they flatten under their own weight, turning into recumbent folds. The advancing folds produce the tectonics of marginal folding and thrusting, the peel thrusts, and the wholly superficial phenomena of thrust flows and tilt flows. Where mobile magma bodies reach higher levels in large volume, they dominate the structure. Flattening under their own weight, they produce similar though more localized and irregular effects on the foreland.

Orogenesis in all its aspects is thus the most conspicuous result of the action of gravity which molds the stereosphere in response to the volume changes in the strictosphere.

Notes on refinements in refraction technique, and adaptation to near-surface corrections

H. L. MENDENHALL, Phillips Petroleum Company

For abstract see Proceedings of the Geophysical Society of Tulsa, v. 4, 1956-57, p. 79

The use of geophysics in the development department

PETER B. BIKE, Seaboard Oil Company

For abstract see p. 56

The Tools of our Profession

JACK D. WALLNER, Seaboard Oil Company

The application of a variety of exploration tools is described in the location, delineation, and re-evaluation of a piercement salt dome off the Louisiana coast. By the use of gravity, refraction, and reflection methods, coupled with a dip meter survey, and the integration of geology and geophysics, an increasingly accurate picture of the salt dome was obtained.

The SEG—problems and potentialities

O. C. CLIFFORD, JR., The Atlantic Refining Company

Paleomagnetism

DR. S. K. RUNCORN

For abstract see p. 60

The future of missiles

GEORGE H. CRAIG, Convair Aircraft Company

The electronic computer: a new tool for today's seismic interpreter

FRANK P. TROSETH, Magnolia Petroleum Company

The electronic computers available today provide geologists and geophysicists with a new tool for finding oil. The ability of these machines to process a large amount of data accurately and speedily makes them particularly helpful to the seismic interpreter. By recording well formation tops, well velocity survey data, seismic reflection times, and other basic geological and geophysical information, an interpreter can obtain a wealth of information to aid him in his search for oil. Using the supplied information, an electronic computer can provide the interpreter with subsea depths, corrected reflection times, average velocities, interval thicknesses, or any other values which can be derived from the supplied information. The output data from a computer can be printed mechanically in the form of a table, graph, or map.

The examination of interval zones will probably be one of the most profitable activities made available to an interpreter who uses an electronic computer. Isopach information which has previously been available only after many hours of computation and drafting can now be requested almost at will. This means that the interpreter will be able to study many intervals investigating changes in velocity, wave travel time, and thickness. Studies of this type will certainly aid in the delineation of both stratigraphic and structural traps.

FORT WORTH GEOPHYSICAL SOCIETY

Chartered August 7, 1948

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Offshore seismic exploration in the Caribbean

HENRY L. GRANT, Western Geophysical Company

The Caribbean Sea presents every conceivable challenge that can be encountered in marine seismic operations and is, therefore, among the most interesting areas in the world to the geophysicist.

Flexibility of instrumentation is a must. To help solve the many geophysical, geological, and structural problems, crews switch from reflection to refraction shooting on short notice. Special filters and AVC speeds are required. Record sections are an invaluable aid to interpretation of the complex structure of the region. Government permits and restrictions, severe weather, and inadequate port facilities and supplies are some of the operational problems encountered. Electronic surveying systems must be established in each area.

The known geology of the Antillean-Caribbean region, the size of the various continental shelves, and the geophysical challenges which have been met form the basis for extensive offshore activity in the Caribbean.

The future of rocketry

GEORGE H. CRAIG, Convair Aircraft Company

Nuclear Energy and the fossil fuels

M. KING HUBBERT, Shell Development Company

Abstract not received.

Scale in exploration

O. C. CLIFFORD, JR.

For abstract see p. 56

The use of geophysics in the development department

PETER B. BIKE

For abstract see p. 56

Seismic reflections from within the pre-Cambrian basement complex, Oklahoma

M. B. WIDESS, Pan American Petroleum Corporation

Reflections from basement rocks of pre-Cambrian age were recorded in Comanche County, southwestern Oklahoma, in the vicinity of the Wichita Mountains. The reflections, of good quality and extended continuity, provide a section in excess of 80,000 feet of igneous rocks that appears like a seismic section of sedimentary formations.

A well in the area drilled over 4,000 feet of this pre-Cambrian section, encountering alternating layers of different types of igneous rocks exhibiting high contrasts in density. The material involved comprises primarily silicic rocks (granophyres, porphyritic rhyolites, rhyolite) and gabbroic rocks (diabase, gabbro, and basalts). Pre-Cambrian outcrops of much of the Wichita Mountains display sheet-like gently dipping layers, some of which persist for several miles. The seismic reflections are thus produced by the igneous layers of differential acoustic properties. An abrupt change of direction of dip occurring at mid-depth of the seismic section precludes the possibility that the seismic events are multiple reflections.

Paleomagnetism

DR. S. K. RUNCORN

For abstract see p. 60

Resolution of gravity anomalies

E. V. McCOLLUM

For abstract see p. 54

ARK-LA-TEX GEOPHYSICAL SOCIETY

Chartered March 12, 1949

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Qualitative analysis of multiple reflections

W. S. HAWES, Seismic Explorations, Inc.

Seismic records from southern Alabama exhibiting strong multiple reflections are presented together with auxiliary data designed to yield a qualitative analysis of the specific

case. In conjunction, several aspects of the general problem of multiple reflections are considered; surface and subsurface factors conducive to generation of high level multiples, the compounding effect of two or more strong reflectors, and methods for detection of multiples.

Miniaturization of electronic equipment by the use of transistors

GUY RAMBIE, Texas Instruments, Inc.

Abstract not received.

The seisverter

E. J. CROSSLAND and JAMES E. HAWKINS

For abstract see p. 55

Vibrations

Film by Hercules Powder Company

Scale in exploration

O. C. CLIFFORD, JR.

For abstract see p. 56

Geophysics and geopolitics

PAUL L. LYONS and BEN F. RUMMERFIELD

For abstract see p. 56

PERMIAN BASIN GEOPHYSICAL SOCIETY

Chartered January 30, 1950

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Getting your feet on the ground velocity-wise

C. H. THURBER, Empire Velocity Service

Abstract not received.

Directivity effect of elongated charges

A. W. MUSGRAVE, G. W. EHLERT and D. M. NASH, JR., Magnolia Petroleum Company

For complete paper see GEOPHYSICS, v. 23, 1958, p. 81-96.

The future of rocketry

GEORGE H. CRAIG, Convair Aircraft Company

Qualitative analysis of multiple reflections

W. S. HAWES

For abstract see p. 62

Where is tomorrow's oil coming from

JOHN H. MURRELL, DeGolyer and Mac Naughton

DENVER GEOPHYSICAL SOCIETY

Chartered May 19, 1950

From the bottom up

ROY F. BENNETT, Sohio Petroleum Corp.

The results of exploration during the past decade indicate a constantly rising cost per barrel for new reserves found. Statistical trends indicate that our present exploration programs and thinking will not long provide our crude oil demands within our own country It is suggested that exploration thinking be reoriented to conform with the depositional history of petroliferous basins — from the bottom up.

Geophysical instruments and deep holes provide data on the older, deeper structural framework which affected subsequent deposition.

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Qualitative analysis of multiple reflections

W. S. HAWES

For abstract see p. 62

The key variables of gravity

FREDERICK ROMBERG

For abstract see p. 55

Scale in exploration

O. C. CLIFFORD, JR.

For abstract see p. 56

Geophysics and geopolitics

PAUL L. LYONS and BEN F. RUMMERFIELD

For abstract see p. 56

Transient behavior of patterns

J. E. WHITE, Ohio Oil Company

For complete paper see GEOPHYSICS, v. 23, 1958, p. 26-43.

Resolution of anomalous masses

E. V. McCOLLUM

For abstract see p. 54

Recommended practices in the handling and use of seismic explosives

T. L. McCORKLE, E. I. du Pont de Nemours & Co.

This paper is based on a series of 35 mm. color transparencies showing typical seismic operations in Wyoming, offshore along the Gulf Coast, and in a Louisiana swamp. Emphasis is placed on the proper methods for handling and using explosives in these vastly different types of work. The author discusses the pictures as they are presented, pointing out good and bad practices, and comments on safety in general from the standpoint of an explosives manufacturer.

CANADIAN SEG

Chartered January 24, 1952

From the bottom up

ROY F. BENNETT

For abstract see above

Geophysical work in the Atlantic Ocean

SIR EDWARD C. BULLARD, Cambridge University, England

Abstract not received.

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

The international geophysical year

J. TUZO WILSON, University of Toronto

The human element in geophysics

CECIL H. GREEN, Geophysical Service, Inc.

It can be stated that the degree of success attained by a business enterprise will in the future be increasingly dependent not only on technical skill but also upon management ability and just how well we coordinate these two ingredients. It is felt that this premise is applicable to the petroleum exploration industry, particularly since we are now experiencing a major expansion effort around the world.

Synthetic seismic reflection studies

H. R. BRECK, NOEL FROST and S. W. SCHOELLHORN,
Seismograph Service Corporation

For abstract see p. 52

An introduction to the general-purpose electronic analog computer

V. C. LARSON, Imperial Oil Ltd.

Abstract not received.

GEOPHYSICAL SOCIETY OF OKLAHOMA CITY

Chartered September 30, 1952

Travelogue on France and Africa

R. E. McMILLEN, Midstates Oil Corp.

From the bottom up

ROY F. BENNETT

For abstract see p. 64

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Intensity modulated cathode ray tube section plotter

R. W. KELLY, Texas Instruments, Inc.

The use of the cathode ray tube beam provides a rapid and versatile method of recording seismic records on photographic film. By employing somewhat conventional time sharing techniques, 24 channels of seismic information can be presented simultaneously as an intensity modulated signal on the cathode ray tube beam. The sweep rate in the vertical direction can be controlled such that velocity information can be applied to the writing beam and a depth section may be presented. An electronic curve shaping network may be used to compute the normal move out error. This error then may be caused to displace each trace in a vertical direction through a mixing circuit to give the appearance of a time delay. Similarly a DC voltage can simulate constant

time corrections causing a further displacement of the individual traces. The result is a completely time corrected variable density seismic record which may be photographed by means of a cathode ray tube and an oscilloscope camera.

By advancing the film holder a record section may be built up. Calibration means may be provided either in feet or in time by pulses that appear along the side of the record. Mixing may be provided in the phosphor of the cathode ray tube by special horizontal sweep mixing circuits. Shot stacking may be obtained by double exposure of the photographic negative.

Future growth and financial requirements of the world petroleum industry

KENNETH E. HILL, Chase Manhattan Bank

Where is tomorrow's oil coming from

JOHN H. MURRELL, DeGolyer and MacNaughton

Interval velocity logs

M. P. TIXIER, Schlumberger Well Surveying Corp.

The principle, the apparatus, and the method of operation are described. The log, which is recorded by a two-receiver system, is independent of hole size and mud. The interpretation of the log is based on field experience. A discussion of porosity values determined from measured velocities in hard formations and compacted sands is given. The calculation of porosities in limestones, cemented sandstones, and compacted sands has for its basis M. R. J. Wyllie's time average formula. Porosity calibration is not noticeably affected by differences in the composition of the limestones.

That considerable attenuation of sonic energy takes place in fractured formations has been shown by field experience. When unusually large attenuation takes place, skipped cycles occur. This feature is easily recognized. Correlation and its application to the interpretation of seismic surveys are reviewed.

Paleomagnetism

DR. S. K. RUNCORN

For abstract see p. 60

The earth satellite program

T. F. FOX, Tinker Air Force Base

Visual satellite observations

WALTER A. MUNN, Smithsonian Astrophysical Observatory

Applications of the densilog

R. H. ANDERSON, Lane Wells Company

The densilog is a graph of gamma ray radiation intensity versus depth of a drilled hole and serves as a valuable tool for determining formation density and porosity.

The instrument consists of 1.) a gamma ray source of known intensity, 2.) a gamma ray detector, 3.) a leaf spring to hold the instrument in contact with the formation, and 4.) a suitable shielding arrangement around the source and detector.

Only those gamma rays reaching the detector through the unshielded side of the instrument are used. The only appreciable shielding of these rays is supplied by the formation. The amount of shielding that the formation offers is proportional to its density. The radiation intensity measured may be converted to density by use of suitable calibration graphs and the porosity calculated.

CASPER GEOPHYSICAL SOCIETY

Chartered May 23, 1953

Directivity effect of elongated charges

A. W. MUSGRAVE, G. W. EHLERT and D. M. NASH, JR.

For complete paper see GEOPHYSICS, v. 23, 1958, p. 81-96.

The importance of structural interpretation of seismic data

R. A. WEINGARTNER, Pan American Petroleum Corp.

For abstract see Proceedings of the Geophysical Society of Tulsa, v. 4, 1956-57, p. 76.

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Synthetic seismic reflection studies

H. R. BRECK, NOEL FROST and S. W. SCHOELLHORN

For abstract see p. 52

Geophysics and geopolitics

PAUL L. LYONS and BEN F. RUMMERFIELD

For abstract see p. 56

Scale in exploration

O. C. CLIFFORD, JR.

For abstract see p. 56

Recommended practices in the handling and use of seismic explosives

T. L. McCORKLE

For abstract see p. 64

The International Geophysical Year

CHARLES L. BRAGAW, National Bureau of Standards

Abstract not received.

Introduction to synthetic seismograms

L. J. LARGUIER, Sohio Petroleum Company

Interpretation of pinchout and stratigraphic changes from seismic records has always been desired. Now, better and more detailed knowledge of seismic velocities resulting from continuous velocity logs makes possible better understanding of the elements of the traces on a seismic record. Construction and study of synthetic seismograms, made either from continuous velocity logs or from electric logs, now lead to the possibility of pinchout and stratigraphic interpretation as well as to the improvement of conventional structural interpretation.

Geophysics and the stratigraphic search for oil

H. M. THRALLS, Geo Prospectors, Inc.

Past performances of geophysics in finding stratigraphic oil are poor but this does not preclude future success. The seismograph, since it has more resolving power than any other geophysical exploration tool, presents the greatest potential for finding stratigraphic traps. It has already been very helpful in some cases in guiding lease plays and

drilling development once the stratigraphic discovery well has been drilled. Present day tools such as variable frequency response, magnetic recording, continuous velocity logs, and synthesized records provide raw material from which new and previously unknown facts may be revealed. Certain observations lead to the conclusion that the seismograph may become as good a stratigraphic tool as it has been a structural tool if the seismologist can learn enough about his basic information to make a really intelligent interpretation of his records. To accomplish this end, management must cooperate by revising its methods of using geophysical crews.

GEOPHYSICAL SOCIETY OF SOUTH TEXAS

Chartered November 9, 1953

Geology and petroleum development in Mexico

EDUARDO J. GUZMAN, Petroleos Mexicanos

Geophysics of the Edwards Trend in South Texas

W. LEE MOORE, Petty Geophysical Engineering Company

(A popular version of this paper appeared in The Oil and Gas Journal, August 12, 1957.)

Since the discovery of the Luling Field, Caldwell County, Texas, in 1922, geophysics has contributed toward the successful development of the Edwards Trend in South Texas.

Sample gravity data, typical reflection records, and a cross-section of a faulted zone in the Edwards illustrate the effectiveness of a geophysical program toward the common goal of both the geologist and the geophysicist — to find more petroleum reserves.

Contouring problems of geologists and geophysicists

PORTER A. MONTGOMERY, Pan American Petroleum Corp.

Abstract not received.

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

Directivity effect of elongated charges

A. W. MUSGRAVE, G. W. EHLERT and D. M. NASH, JR.

For complete paper see GEOPHYSICS, v. 23, 1958, p. 81-9(

The story of Colonel Drake

Film by American Petroleum Institute

Development of salt dome graben structures

Film by Gulf Research and Development Corp.

Visit to Southern Mexico

PORTER A. MONTGOMERY, Pan American Petroleum Corp.

Modern concepts in reflection seismology

DR. F. A. VAN MELLE, Shell Oil Company

For abstract see p. 53

Portrait of the earth

Film by Hycon Corp.

SOUTHEASTERN GEOPHYSICAL SOCIETY

Chartered April 1, 1954
(partial listing)

Art—the Midas touch to geophysics

R. H. HOPKINS, Sun Oil Company

Geophysics, although based on sound physical reasoning, does not always admit a unique answer to a given problem. Unknowns, such as hidden weathering, density contrasts, magnetic susceptibilities, etc., cause vague or incorrect answers. A partial remedy for this is the use of experience and common sense. Knowing when to take a few liberties with theory, and knowing when to throw out some of the data can save many borderline jobs.

Qualitative analysis of multiple reflections

W. S. HAWES

For abstract see p. 62

MONTANA GEOPHYSICAL SOCIETY

Chartered April 12, 1954

Directivity effect of elongated charges

A. W. MUSGRAVE, G. W. EHLERT and D. M. NASH, JR.,
Magnolia Petroleum Co.

For complete paper see GEOPHYSICS, v. 23, 1958, p. 81-96.

Seismology and the earth's deep interior

DR. K. E. BULLEN

For abstract see p. 52

If the atom bomb falls

Film

Qualitative analysis of multiple reflections

W. S. HAWES

For abstract see p. 62

Topography and its apparent effect on average velocity

H. M. THRALLS, Geo Prospectors, Inc.

For complete paper see p. 31

Scale in exploration

O. C. CLIFFORD, JR.

For abstract see p. 56

Geophysics and geopolitics

PAUL L. LYONS and BEN F. RUMMERFIELD

For abstract see p. 56

Introduction to synthetic seismograms

L. G. LARGUIER

For abstract see p. 67

The International Geophysical Year

CHARLES L. BRAGAW, National Bureau of Standards

Abstract not received.

A system of processing and displaying magnetically recorded data

ROBERT S. FINN, Seismograph Service Corp.

The use of magnetic recording makes possible various methods of handling field seismic data, which can improve interpretability of the data and which are not practical with conventional recording. Also data can be displayed in various forms which can make interpretation easier, more accurate, and more complete. These display forms usually consist of corrected record cross-sections made with conventional galvanometer traces, variable area traces, or variable density traces. This paper will discuss a specific magnetic replay system and its cross-section presentations, with examples of the results.

JACKSON GEOPHYSICAL SOCIETY

Chartered May 12, 1955

Modern concepts in reflection seismology

DR. F. A. VAN MELLE

For abstract see p. 53

The key variables of gravity

FREDERICK ROMBERG

For abstract see p. 55

Qualitative analysis of multiple reflections

W. S. HAWES

For abstract see p. 62

Synthetic seismic reflection studies

H. R. BRECK, NOEL FROST and S. W. SCHOELLHORN

For abstract see p. 52

Art—the Midas touch to geophysics

R. H. HOPKINS

For abstract see p. 69

A new look at Mississippi deep tests

PAUL WEAVER, Texas A. & M.

Affairs of the SEG

O. C. CLIFFORD, JR., The Atlantic Refining Company

Geophysics and geopolitics

PAUL L. LYONS and BEN F. RUMMERFIELD

For abstract see p. 56

Mixing—why and why not

PHIL P. GABY, Delta Exploration Company

The advent of magnetic recording makes it desirable to review the use of electronic mixing of seismic energy. For example, when a tape is played back using static and

dynamic corrections, all reflection signals are in zero phase except for the time-slope produced by the formation dip.

Mixing terminology is briefly explored and various types of mix identified in terms of "trace composition" and "trace similarity".

The fear that mixing will "smear the evidence of fault crossings" or will create "spurious" events is investigated in the following manner. A tape is recorded at ⅓ normal level of a shot in a good area where a single group activates all 24 magnetic tracks so that all signals are identical. On playback the heads are shifted to simulate "steep dip", a one cycle fault, flat dip and a ½ cycle fault. The tape is then played back and recorded straight, and with various types of mix. All events are identical and there is no smearing of fault crossings and no new or spurious events created.

A second tape, made from a conventional field set-up with full scale purely random noise (without firing a shot), is combined with the first, and the summation recorded straight and with various types of mix.

On the straight record, reflection energy can be seen but no reflections picked (the signal-noise ratio is ⅓). Through use of mix the original record can be recovered with the noise almost entirely eliminated. Each fault crossing can be seen and there is no evidence of smearing and no new or spurious events were created. These synthetic faults bear a striking resemblance to certain peculiar events occasionally seen on seismograms.

SOUTHWEST LOUISIANA GEOPHYSICAL SOCIETY

Chartered January 4, 1956
(Partial Listing)

Blasting vibrations, causes and effects

Film.

A simple method for determining the depth of shallow salt domes by refraction shooting

PAUL C. REED, Texas Pacific Coal and Oil Company

This paper presents in very simple terms a procedure whereby refraction seismograph may be used to determine the depth to the top of shallow salt domes. The various steps necessary to obtain and compute the data are described and diagrammed in a manner such that the Party Chief, Seismologist or the Computer is able to lay out the program, reduce the data, and arrive at a straightforward interpretation and solution. The paper is virtually non-technical, and because of its simplicity, the author believes that geophysicists and exploration groups operating in the salt dome provinces will find it helpful.

UTAH GEOPHYSICAL SOCIETY

Chartered October 29, 1956
(partial listing)

Use of dipmeter in subsurface interpretations

MELVIN O. DUKE, Consultant

Abstract not received.

Qualitative analysis of multiple reflections

W. S. HAWES, Seismic Explorations, Inc.

For abstract see p. 62

Comparison of seismogram cross-sections recorded in various modes

F. S. KRAMER, O. W. SCHOENBERG and R. A. PETERSON,
United Geophysical Corp.

For abstract see p. 57

Laboratory investigation of compressional wave velocities

JOSEPH W. BERG, JR. and KENNETH L. COOK, University of Utah

For the past two years, members of the Geophysics Department of the Univ. of Utah have been studying propagational velocities of compressional elastic waves through porous media at standard conditions of temperature and pressure. Piezo-electric transducers were used for both wave source and receiver. The variables that have been considered are; mineralogical composition (other than cement), porosity, amount and type of cementing material, type of saturating liquid, and environmental conditions (manufacturing pressure of synthetic sandstone).

The experiments made largely on liquid-saturated synthetic sandstone cores, indicate that the tentative respective order of importance of the factors controlling velocity is:

1. Porosity—For porosities of about 25%, the velocity increased about 2% for a 1% decrease in porosity.

2. Type of Saturating Liquid—For a porosity of about 20% and a mfg. pressure of about 12,000 psi, the velocity was varied 20% by using different types of saturating liquid. This effect tends to become second order at the lower porosities.

3. Manufacturing Pressure—For mfg. pressures less than 8,000 psi, the velocity was increased approximately 1.5% with an increase in pressure of 4,000 psi.

4. Cement Content—For a porosity of about 25% and a cement content ranging between 10% and 17.5%, the velocity increased about 0.5% for a 1% increase in cement content.

5. Type of Cementing Material—The velocity decreased as the binding strength of the cement decreased.

Insufficient data are available to indicate the relative importance of the mineralogical composition of the frame for argillaceous sandstones, etc.

CONSTITUTION AND BY-LAWS

(*As amended to April* 10, 1958)

ARTICLE I

The name of this Society is the *Geophysical Society of Tulsa*. It shall be the Tulsa Section of the Society of Exploration Geophysicists.

ARTICLE II

OBJECT

The object of this Society is to promote the science of geophysics especially as it applies to exploration, and to promote fellowship and cooperation among those persons interested in geophysical problems.

ARTICLE III

MEMBERSHIP

1. Any person interested in the geophysical profession shall be eligible for membership.
2. Applications for membership shall be submitted in writing, and shall be signed by three sponsors who are members of the Society.
3. Application shall be approved for membership by the Executive Committee.
4. The annual dues of members of the Society shall be three dollars ($3.00) payable in advance on the first day of each calendar year.
5. Members whose applications are approved after July 1 shall be required to pay only one-half the regular annual dues for the remainder of the first year of their membership.
6. Charter Members of this Society will be those who attended the first organizational meeting of the Society on February 4, 1947, or who attended the second meeting on March 13, 1947, and signed the respective roll as charter members, and who have paid dues for the year 1947.
7. Honorary Members of this Society shall be elected by unanimous vote of the Executive Committee. To be eligible for Honorary Membership, a person must have attained the age of sixty and must have made outstanding contribution or contributions to the geophysical profession in general or to this Society in particular. Honorary Members shall receive all publications and meeting announcements of the Society but shall not be required to pay dues or any special assessments.

ARTICLE IV

RESIGNATION AND SUSPENSION

1. Any member may resign from the Society at any time. Such resignation shall be in writing and shall be accepted by the Executive

Committee, subject to the payment of all outstanding dues and obligations of the resigning member.

2. Any member who is more than one year delinquent in payment of dues shall be suspended from the Society. Any delinquent or suspended member, at his own option, may request in writing that he be dropped from the Society and such request shall be granted by the Executive Committee after due notification. Any member more than two years in arrears shall be dropped from the Society.

3. Any person who has ceased to be a member under Section I or Section 2 of the Article may be reinstated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member of the Society.

ARTICLE V

OFFICERS AND THEIR DUTIES

1. The officers of the Society shall be: President, First Vice-President, Second Vice-President, Secretary, Treasurer, and Editor.

2. There shall be district representatives to the Society of Exploration Geophysicists, as provided in the constitution of that society.

3. The Executive Committee shall consist of the Officers, the two most recent available Past Presidents, and the District Representative, or representatives, to the Society of Exploration Geophysicists.

4. The Officers shall be elected by a ballot as hereinafter provided at the Annual Meetings, and shall hold office for one year.

5. The President shall preside at the meetings of the Society and of the Executive Committee. He shall call special meetings when deemed advisable; shall appoint all committees except as otherwise herein provided; and, jointly with the Secretary-Treasurer, shall sign all written contracts and other obligations of the Society. In the temporary absence of other officers, he shall assume their duties or delegate them.

6. The First Vice-President shall be responsible for arranging the technical program of the Society, and shall have authority to appoint such assistants as he may require. He shall perform the duties of President in the absence or disability of that Officer, and in case of the President's resignation shall become President for the remainder of the term.

7. The Second Vice-President shall be responsible for arranging entertainment, and shall have power to appoint members to assist him.

8. The Secretary shall maintain a complete list of the membership of the Society and of its Executive Committee, shall mail advance notice of meetings to all members, shall keep minutes of meetings of the Society, and of its Executive Committee, shall notify the members by mail of proposed amendments to the Constitution, and shall mail and receive ballots.

   The Secretary shall submit to the Secretary-Treasurer of the Society of Exploration Geophysicists a report of each meeting of this Society

and of its Executive Committee within two weeks following each such meeting. He shall also submit to the Secretary-Treasurer of the Society of Exploration Geophysicists the names of all Officers and Committee members within two weeks after their election or appointment.

9. The Treasurer shall collect all dues and other obligations to the Society, shall make disbursements authorized by the Executive Committee and shall transact such other business as may be authorized by the Executive Committee. He shall maintain a chronological record of all receipts and expenditures as well as a system of records explaining each expenditure, including evidence of authority to expend funds and evidence of payment. He shall report the condition of the Treasury at each Annual Meeting and at other times upon request of the Executive Committee.

   When so instructed by the Executive Committee, he shall make application to the Secretary-Treasurer of the Society of Exploration Geophysicists for such portion of the expenses to be borne by that Society, as may be needed, and shall submit to the Secretary-Treasurer of the Society of Exploration Geophysicists, prior to the annual meeting of that Society, an itemized account of the expenditure of such funds as may have been received from the Society of Exploration Geophysicists during the preceding calendar year.

   A quorum of the Executive Committee shall consist of at least four members and approval by at least four members will be necessary to conduct all business of the Society.

10. The Editor shall be in charge of the editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the regular society publication and for special publications, and may accept or reject material offered for publication. He may appoint editorial assistants.

11. The Executive Committee shall transact all business of the Society not otherwise herein specifically provided for. It shall elect all members to the Society, shall authorize all expenditures, shall direct investments of Society funds, shall establish and supervise publications; shall approve and recommend all proposals for special assessments; shall fill vacancies occurring in any office except in the office of President, to which the First Vice-President automatically succeeds, and shall have the power to review all actions and appointments by the Officers.

12. The District Representatives of the Society of Exploration Geophysicists shall represent the Society and its members at meetings of the Council of the Society of Exploration Geophysicists.

ARTICLE VI

ELECTION OF OFFICERS

1. A slate of nominations for officers shall be prepared by a Committee of Nominations consisting of the President and the two most recent available Past Presidents. They must secure the consent of all candidates nominated. This slate, of two or more candidates for each office, shall be prepared and announced to the Society at its regular meeting in March of each year.

Additional nominations for each office may be made by written petition of ten or more members in good standing. Such nominations must be submitted to the President not later than the close of the regular meeting in April.

The election of officers shall be by secret mail ballot. The Secretary shall mail to all members, not later than three weeks preceding the Annual Meeting, a ballot listing all candidates properly nominated for each office. Each member voting shall cast one vote for each officer and shall return his ballot to the Secretary in a sealed envelope carrying on the outside his written signature. Only ballots so prepared by members in good standing and received by the secretary by 4 P.M. on the Monday immediately preceding the Annual Meeting shall be valid.

The Secretary shall indicate which ballots are valid and shall deliver them unopened to the Committee on Nominations. The Committee on Nominations shall supervise the counting of ballots prior to the Annual Meeting. The candidates receiving the greatest number of votes cast for an office shall be declared elected to that office. In case of a tie, the Executive Committee shall decide which of the tied candidates shall be elected.

2. The Committee on Nominations shall prepare a slate of nominations for any posts of district representatives to the Society of Exploration Geophysicists, which may need to be filled. Additional nominations may be made in the manner set forth in Section 1. The election shall be by secret ballot at least three weeks prior to the annual meeting of the Society of Exploration Geophysicists.

ARTICLE VII

MEETING

1. The Annual Meeting shall be held in May of each year, and shall be held on the second Thursday of May, unless otherwise specified by the Executive Committee and due notice given to the membership.
2. The Regular meetings of the Society shall be held on the second Thursday of each month except during the months of June, July, and August, unless otherwise provided by the Executive Committee.
3. Special meetings may be called at any time by the President of the Society.
4. The time and place of regular meetings, the nature of the technical program and the entertainment, shall be determined by the Excutive Committee.

ARTICLE VIII

AMENDMENTS

1. This constitution may be amended by a three-fourths vote of the members present at any regular meeting, provided that the proposed amendment has been approved for submittal by the Executive Committee and has been moved at a regular meeting previous to the meeting at which the ballot shall be taken.
2. By-laws may be changed by majority vote of members present at any regular monthly meeting.
3. Nothing in this Constitution or By-laws shall be inconsistent with the Constitution and By-laws of the Society of Exploration Geophysicists.

BY-LAWS

I. The Officers and the Executive Committee may arrange for the affiliation with other duly organized groups or societies which by object, aims, constitution or practice are aiding, assisting, or developing the profession of geophysics or allied technology.

II. Until such time as a sufficient number of qualified Past Presidents has been created, so as to provide those members necessary to serve on the Executive Committee as provided in the constitution, these Executive Committee members shall be chosen by the Society by a majority vote from open nominations at the Annual Meeting.

III. Prior to the Annual Meeting the Treasurer shall close his accounts and submit them to a committee of three members of the Executive Committee designated by the President. These members shall audit the accounts and then certify their correctness by signing an entry in the cash book.

The new Treasurer shall accept the Society funds by giving an entry to that effect in the cash book.

IV. The Society shall publish a journal. The journal shall be published at intervals designated by the Executive Committee. All reports to the Society by its officers and committees may be published in the journal. Each issue shall contain a membership list. Each issue shall list all committees. Original papers, reviews, abstracts, notes or information deemed by the Editor to be of interest to the members of the Society shall be published in the journal. The editor shall be sole judge of whether such material is to be published. The Executive Committee may authorize the printing of the journal and may authorize financing and distribution of the journal.

V. The first editor may be elected at a regular session of the Society following passage of this by-law at a regular meeting.

RULES FOR THE ADMITTANCE OF NEW MEMBERS

1. Any person interested in the geophysical profession shall be eligible for membership in the Geophysical Society of Tulsa.
2. Applications for membership shall be submitted in writing, and shall be signed by three sponsors who are members of the Society.
3. Applications shall be approved for membership by the Executive Committee.

Note: The Constitution was originally adopted March 13, 1947. It was amended January 8, 1948, November 11, 1948, February 9, 1950, November 13, 1952, and April 10, 1958. The By-Laws were amended February 9, 1950, and November 13, 1952.

GEOPHYSICAL SOCIETY OF TULSA

ACTIVE MEMBERSHIP ROLL

AS OF MAY 1, 1958

Abel, Karl W.	Mayes-Bevan Co.	
	305 Kennedy Bldg.	Tulsa, Okla.
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	321½ Dewey	Bartlesville, Okla.
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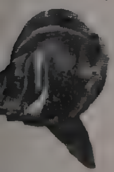

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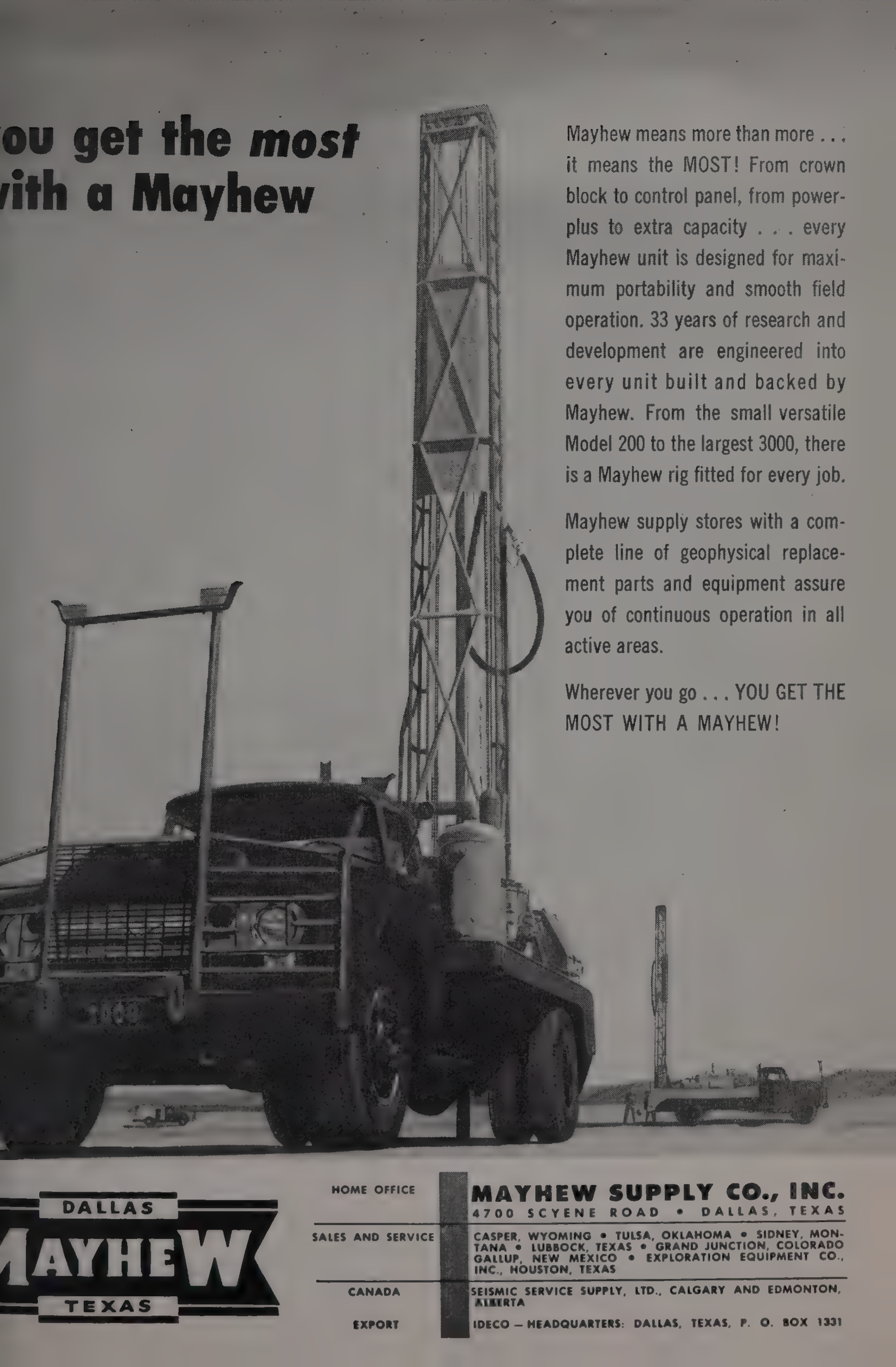
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